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# PROJECT SUMMARIES
## FOR 1989
## Fourteenth Annual
## Review of Activities

Compiled and Edited by

Shasta A. Abbott

NEW BRUNSWICK
DEPARTMENT OF NATURAL RESOURCES AND ENERGY
MINERALS AND ENERGY DIVISION

Canada-New Brunswick Mineral Development Agreement
Entente Canada-Nouveau-Brunswick L'Exploitation Minérale

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This report has been prepared by:

Minerals and Energy Division
Department of Natural Resources and Energy
Province of New Brunswick

Hon. Morris Green, Minister of Natural Resources
and Energy
Hon. Edmond Blanchard, Minister of State for Mines

1990

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# MESSAGE FROM

HON. EDMOND BLANCHARD
MINISTER OF STATE FOR MINES*
NEW BRUNSWICK

* presented on November 21, 1989 at the Fourteenth Annual Review of Activities (Open House) for the Minerals and Energy Division of the New Brunswick Department of Natural Resources and Energy, Fredericton, New Brunswick.

This is the first opportunity I have had to speak at the Minerals Division "Open House" luncheon. Hopefully, I will be able to stand before you again next year and bring you good news about improvements and developments in the mining industry in New Brunswick.

The past year has seen a number of positive developments for the mining industry in New Brunswick. My appointment as Minister of State for Mines last June was a positive move on behalf of the government.

It underscores our government's commitment to future growth of the mining industry. I am able to concentrate fully on this facet of the Province's resource base.

Last year my colleague, the Honourable Morris Green, spoke of our commitment to mineral development and to our interest in opening up potash to staking. He also spoke about our efforts in research and development in both the environmental and reclamation aspects of mining.

Just last night, I had the pleasure of informing members of the New Brunswick Prospectors and Developers Association that we have had our potash policy approved by government and hope to have the information package in connection with that policy ready by next spring.

Basically, the policy will allow a company or individual to obtain a "licence to search" which will cover a minimum area of 25-thousand acres. The licences will be issued on a first-come-first-served basis for any given area.

Since last November, the concern with mine acid tailings and waste rock, especially in the sulphide mining camp, has received considerable attention. As you may be aware, the Province is supporting research and development work in the Mine Environment Neutral Drainage, or MEND program by funding the Heath Steele waste sulphide rock study along with Brunswick Mining. It is anticipated that the study will provide methodologies for the reclamation of acid-generating waste rock sites in northeast New Brunswick.

The importance the government places on the MEND program will also be reinforced in the new Mineral Development Agreement. The ultimate objective of the MEND research and development work is to develop a "walk-away" solution to acid mine drainage, thereby removing one of the constraints to sulphide mine development.

The environmental impact of mining, both in the exploration and production stages is also a matter of concern. More effort is required of drilling and exploration companies to reclaim disturbed sites. This involves drill-site clean-up and the contouring of trenches. As I mentioned earlier, the major

concern with producing properties is the generation of acid water from oxidizing sulphides and the potential damage of trout and salmon streams and rivers.

We hope that the MEND program will be able to provide a solution to the problem. If the problem is not solved quickly, then the days of mining sulphides will come to an end in environmentally sensitive areas.

The industry and our Department share concerns about the treatment of post-production reclamation costs by the federal and provincial taxation system. The Intergovernmental Working Group has accepted the concept of establishing a provincially-mandated program which would allow mining companies to contribute a fixed amount on a regular basis to a reclamation fund for mine-site rehabilitation.

We are proposing that the contributions be deductible for taxation purposes during the year of contribution. The fund would be used by the company to reclaim the disturbed lands. Funds not used would return to the company and would be taxable. Each of the jurisdictions is now examining the implications of such a fund with their revenue departments.

Our Department has prepared a package for the next Mineral Development Agreement, and at the moment negotiations are continuing between the Province and Ottawa. It is anticipated that the Agreement will be signed before the end of March 1990, which is the termination of the carry-over year of the present MDA.

The budget distribution toward geoscience and mineral development will be approximately 50/50. The package involved in the MDA reflects your input and has been streamlined to recognize the overall budget allotment.

We have been working on a number of other issues that have an impact on all the resources under the jurisdiction of the Department of Natural Resources and Energy. With particular reference to the mining industry, these concerns are the designation of watersheds, ecological reserves, environmental impacts and improving the mine approval process.

The Minerals Division is developing guidelines along with the Crown Lands Branch in their on-going discussions with the Department of Environment with respect to exploration and mine development within watershed areas.

Currently, studies are being carried out on several watersheds by various consultants. It is important that you, the mining industry, pay attention to any public input into the watershed designation studies.

Another issue affecting the industry is the designation of ecological reserves. Fifty-nine potential areas have been identified on the claim maps. Some of these sites will probably not be proclaimed.

Ecological reserves come under Morris Green's jurisdiction and, therefore, the industry should ensure their representation at the compulsory public meetings that are held to gather public input.

There are about 940 mineral claim equivalents or mineral lands tied up until the process is completed. Ecological reserve designation is an on-going process and your comments on such designations are important to the outcome. At present, three areas have been declared ecological reserves and four are in the "Memorandum to Executive Council" stage.

Progress on the mine approval process has not advanced as quickly as we had hoped. However, Mr. Green, the Honourable Vaughn Blaney, and I have established a standing committee on mining and the environment.

The committee will address several issues such as reclamation and rehabilitation securities ... Environmental Impact Assessment screening approvals ... mine reclamation approvals ... the decision-making process ... legislative definitions ... duplication of legislation ... and the mine approval process.

A work schedule to address these issues will also be prepared to ensure that a timely solution to the problem is forthcoming.

There are other problems which the industry could assist in solving. At the recent Mines Ministers' Conference in Sudbury, a preview of the Angus Reid survey showed that in the eyes of the Canadian people, the mining industry was not doing a good job as far as the environment was concerned. The public image of the industry's attitude toward the environment within mining communities was a little better.

The industry will have to work harder in explaining the value of minerals and mining to the Canadian public. At the same time, the industry should draw attention to the positive things it is doing in order to work harmoniously within the environment.

It is interesting to note an editorial in the October issue of Canadian Mining Journal. In commenting on the increasing environmental concern within the mining industry, Jane Werniuk, the editor of C-M-J, says one of the reasons she became a geologist was the opportunity to spend a lot of time in remote, unspoiled places.

She also mentions a sermon in which the speaker quoted from the Books of Genesis and Deuteronomy to show that God gave man dominion over all the earth, but with humility. Having dominion includes the obligation to preserve the land in a state fit for all living things, including our children.

I highly commend Jane Werniuk for her comments. If you haven't already read her editorial, I strongly recommend that you do so as soon as possible.

As you are already aware, our government has made a strong commitment to protecting the environment. But we have an equally strong commitment to providing viable employment for our citizens. With that in mind, we intend to pursue vigorously our program of value-added processing within the mining industry in the Province.

It is in the interest of the people of New Brunswick to enhance our economic base by creating permanent, satisfying jobs. This can be done by further processing our minerals within the Province.

In closing, I would like to review the progress made this year in mining. We have three new mines on stream, namely NovaGold, Heath Steele Mines with its Stratmat and N-5 properties and the East West Caribou mine. Currently, the three operations have created 295 jobs which could reach 465 once designed capacities are reached.

It is expected that the total value of mineral production will surpass the 1988 figure of 831-million dollars and a work force of five-thousand people.

Exploration activities have remained strong especially in the northeast. There are two companies currently in the Environmental Impact Assessment process and lease application stage respectively and they should be coming on stream in 1990. All of this continues to make mining a growth industry.

In view of the importance of the mineral industry to New Brunswick, exploration and development of mineral deposits is a priority for the government. We intend to encourage exploration and development of our minerals.

We must develop the technology to co-exist with the environment and we must develop the skills to explain what mining is all about. With new policies and technologies, we will see the Province's mineral potential fully developed.

Thank you.

The following press release was read by Ernest Brooks, Exploration Geologist for Brunswick Mining and Smelting Corporation Limited, during the Open House luncheon:

**PRESS RELEASE - November 21, 1989**

Recent exploration drilling to the north of Brunswick No. 12 Mine has revealed a potentially new sulphide zone. Hole A-248, a deep hole from surface, intersected a 13.4 m lens of massive sulphides, nearly 2 km north of the No. 3 shaft and 1100 m below surface. Assays for the hole are: 8.5 m of 4.61% Pb, 9.91% Zn, 0.22% Cu, 183.4 g/t Ag, 1.65 g/t Au, followed by a pyrite section of 4.9 m of 0.55% Pb, 1.50% Zn, 0.18% Cu, 17.5 g/t Ag, 0.34 g/t Au. The surface hole was a follow-up of a massive pyrite intersection, encountered in underground exploration drilling from 1000 Level in September, 400 m to the south of A-248.

The possibility of additional separate ore lenses to the north of the No. 12 Mine, had first been suggested by C. Van Staal during his thesis work at Brunswick.

The discovery was based solely on geology, utilizing structural and stratigraphic data. This demonstrates Brunswick's exploration commitment to applying information gathered on mine geology to explore for new sulphide deposits. Drilling is continuing on the zone, using one drill from underground and one drill from surface.

For further information, please contact:

William M. Luff
Chief Mine Geologist
(506) 547-6064

or

Jeff Hussey
Project Geologist
(506) 546-6671

**ALLOCUTION DE**

**L'HONORABLE EDMOND BLANCHARD**
**ministre d'état aux mines***
**du nouveau-brunswick**

* Prononcée le 21 novembre 1989 lors de la quatorzième revue annuelle des activités (journées portes ouvertes) de la division des Minerais et de l'Énergie du ministère des Ressources naturelles et de l'Énergie du Nouveau-Brunswick, Fredericton, Nouveau-Brunswick.

Mes chers amis, c'est la troisième fois que j'ai l'occasion de m'adresser à vous à l'occasion du dîner "Portes ouvertes" de la Division des minerais. Avec un peu de chance, j'aurai l'occasion de m'adresser à vous de nouveau l'année prochaine afin de vous faire part des améliorations et des nouveaux développements relatifs à l'industrie minière du Nouveau-Brunswick.

L'année qui vient de finir a été fructueuse en développements positifs pour le secteur minier du Nouveau-Brunswick. Ma nomination, en tant que ministre d'Etat aux Mines en juin dernier, constitue une démarche positive de la part du gouvernement.

Cela confirme l'engagement de ce gouvernement vis-à-vis de la croissance future du secteur minier. J'ai désormais tout loisir de concentrer mon énergie sur cette facette particulière des ressources de la province.

L'année dernière, mon collègue, l'honorable Morris Green, a parlé de notre engagement relativement au développement du secteur minier et de notre désir d'autoriser la prospection de la potasse. Il a également souligné nos efforts de recherche et de développement en matière d'environnement et de remise en valeur des sites miniers.

Justement, hier soir, j'ai eu le plaisir d'annoncer aux membres de la New Brunswick Prospectors and Developers Association que notre politique sur la potasse avait été approuvée par le gouvernement et qu'une trousse d'information sur le sujet devrait être disponible dès le printemps prochain.

En bref, cette politique permettra aux sociétés et aux particuliers d'obtenir un "permis de prospection" pour un secteur ayant au minimum de vingt-cinq mille acres. Ces permis seront délivrés selon un mode de "premier arrivé, premier servi" pour tous les secteurs.

Depuis novembre dernier, la question des résidus miniers acides et des roches stériles, surtout en ce qui a trait aux minerais sulfurés, a fait couler beaucoup d'encre. Comme vous le savez peut-être déjà, le gouvernement provincial appuie actuellement les efforts de recherche et de développement en matière de neutralisation des eaux de drainage dans l'environnement minier, ou programme NEDEM, en finançant l'étude sur les déchets de roches stériles acides de Heath Steele, en collaboration avec Brunswick Mining. On pense que cette étude permettra de trouver des méthodes efficaces de remise en valeur des sites de déchets de roches stériles acides du nord-est du Nouveau-Brunswick.

L'emphase mise par le gouvernement sur le programme NEDEM sera également renforcée dans le cadre de la prochaine Entente concernant l'exploitation minérale. L'objectif ultime de ce programme de recherche et de développement est de trouver une solution au problème du drainage des sites producteurs de résidus acides, permettant ainsi d'éliminer les contraintes inhérentes à la mise en valeur du secteur des minerais sulfurés.

L'impact environnemental de l'exploitation minière, tant en matière de prospection que de production, soulève également quelques inquiétudes. Les compagnies minières devront à l'avenir faire plus d'efforts pour restaurer les sites perturbés par les activités de forage et de prospection. Cela veut dire le nettoyage des sites de forage et la délimitation des tranchées. Comme je l'ai mentionné plus tôt, notre principal problème au niveau des propriétés exploitées est l'acidification de l'eau due à l'oxydation des résidus sulfurés, qui constitue une menace pour les ruisseaux et les rivières à saumon et à truite.

Nous espérons que le programme NEDEM saura apporter une solution à ce problème qui, s'il n'est pas résolu rapidement, entraînera malheureusement la fin de l'exploitation de minerais sulfurés dans les régions où l'environnement est fragile.

L'industrie minière et notre ministère partagent les mêmes inquiétudes en ce qui concerne le paiement, à même les taxes fédérales et provinciales, des frais de mise en valeur suite à l'exploitation. Le groupe de travail interministériel étudie présentement l'idée d'établir un programme provincial qui permettrait aux entreprises minières de contribuer, sur une base régulière, un montant forfaitaire à un fonds de mise en valeur des mines.

Nous proposons que la contribution soit déductible d'impôt au cours de l'année du versement. Eventuellement, l'entreprise pourrait retirer les sommes nécessaires à la remise en état des terres puis la partie non utilisée du fonds lui serait remboursée et deviendrait alors imposable. À l'heure actuelle, les responsables examinent les répercussions que la création d'un tel fonds pourrait avoir auprès de leurs ministères du revenu respectifs.

Notre ministère a préparé un ensemble de recommandations en vue de la prochaine Entente concernant l'exploitation minérale (EEM) et, en ce moment, les négociations se poursuivent entre la province et Ottawa. Il est à prévoir que l'EEM sera signée avant la fin de mars 1990, date à laquelle expire l'année de prolongation de la présente entente.

Les affectations budgétaires prévues pour le développement géoscientifique et minier seront réparties à peu près moitié-moitié. L'ensemble couvert par l'EEM reflète vos données et a été organisé de façon à tenir compte de l'ensemble de l'enveloppe budgétaire.

Depuis quelque temps, nous travaillons sur certaines questions qui ont des répercussions sur toutes les resssources relevant du ministère des Ressources naturelles et de l'Energie. En ce qui concerne l'industrie minière, ces questions sont la délimitation de bassins hydrographiques, de réserves écologiques, la définition des répercussions environnementales et l'amélioration du processus d'approbation d'une mine.

Dans le cadre de ses discussions continues avec le ministère de l'Environnement au sujet de l'exploration et du développement miniers dans les secteurs des bassins hydrographiques, la Division des minerais, conjointement avec la Direction des terres de la Couronne, travaille présentement à établir des lignes de conduite.

Actuellement, divers conseillers poursuivent des études sur plusieurs bassins hydrographiques. Il est important que vous, c'est-à-dire l'industrie minière, portiez une attention particulière à l'opinion publique lors des études effectuées en vue de délimiter les bassins hydrographiques.

Un autre point qui touche l'industrie est la désignation des réserves écologiques. On a identifié 59 régions potentielles sur les cartes de claims. Certains de ces sites ne seront probablement pas concédés.

Les réserves écologiques relèvent de ma responsabilité de M. Morris Green et, en conséquence l'industrie devrait faire en sorte d'être bien représentée lors des réunions publiques obligatoires qui ont lieu en vue de réunir les commentaires de la population.

L'équivalent de 940 claims ou de terres recouvrant des gisements attentent l'aboutissement de ce processus. La délimitation des réserves écologiques est un processus continu et vos commentaires sur ces désignations influent largement sur le résultat. À l'heure actuelle, trois secteurs ont été déclarés réserves écologiques et quatre sont à l'étape du Mémorandum au Conseil exécutif.

Dans le cadre du processus d'approbation des mines, les progrès non pas été à la hauteur de nos espérances. Cependant, M. Blanchard, l'honorable Vaughn Blaney et moi-même avons établi un comité permanent sur les mines et l'environnement.

Ce comité traitera de plusieurs points comme les garanties financières pour la remise en état et l'amendement du sol, l'approbation des études d'évaluation d'impact sur l'environnement, l'approbation des plans de remises en état des sols après l'exploitation minière, le processus de prises de décisions, les définitions législatives, le chevauchement des lois, ainsi que le processus d'approbation des mines.

Un calendrier de travail pour traiter de ces questions sera également préparer afin d'assurer qu'une solution au problème soit approuvée.

De son côté, l'industrie peut nous aider à résoudre d'autres problèmes. Lors de la récente conférence des ministres des maritimes à Sudbury, un examen préalable de l'enquête Angus Reid a indiqué qu'aux yeux du peuple canadien, l'industrie minière n'effectue pas un bon travail en ce qui a trait à l'environnement. L'image du public envers l'attitude de l'industrie relativement à l'environnement était légèrement meilleure dans les communautés minières.

L'industrie devra consacrer plus d'efforts pour expliquer la valeur des minerais et des mines au public canadien. Parallèlement, l'industrie devrait attirer l'attention sur ces réalisations positives en vue de travailler en harmonie avec l'environnement.

Un éditorial du numéro d'octobre du Canadian Mining Journal est digne de mention. Dans ces commentaires sur les préoccupations sans cesse croissante relativement à l'environnement dans l'industrie minière, Mme Jane Werniuk, rédactrice du C-M-J, écrivait que l'opportunité de passer de grands moments dans des endroits éloignés et vierges était une des raisons pour lesquelles elle est devenue géologue.

Elle mentionne également un sermon au cours duquel l'orateur citait les livres de la Génèse et le Deutéronome pour montrer que Dieu avait donné aux humains le pouvoir sur la terre mais avec humilité. Possédé le pouvoir sur la terre inclus l'obligation de préserver cette dernière dans un état satisfaisant pour tout ce qui vit, y compris nos enfants.

Je félicite Mme Werniuk pour ses commentaires. Si vous ne l'avez pas déjà fait, je vous recommande fortement de lire son éditorial le plus tôt possible.

Comme vous le savez certainement, notre gouvernement a pris l'engagement ferme de protéger l'environnement. Mais nous nous sommes également fortement engagés à offrir des possibilités d'emplois fiables à nos citoyens. Dans cette optique, nous entendons poursuivre vigoureusement notre programme de plus-value de la transformation au sein de l'industrie minière dans la province.

Il est dans l'intérêt de la population du Nouveau-Brunswick d'améliorer notre base économique en créant des emplois permanents et intéressants. Nous pouvons y parvenir en procédant au raffinement de nos minerais dans la province.

Pour conclure, j'aimerais passer en revue les progrès accomplis cette année dans le domaine minier. Nous avons actuellement dans la province trois nouvelles mines qui sont

entrées en exploitation, à savoir NovaGold, Heath Steele Mines avec ses propriétés de Stratmat et N-5 et la mine East West Caribou. Actuellement, ces trois exploitations ont crée 295 emplois qui pourraient atteindre les 465 une fois que les capacités théoriques auront été atteintes.

Nous prévoyons que la valeur totale de la production de minerais dépassera le chiffre de 831 millions de dollars de 1988, tout en donnant de l'emploi à une main-d'oeuvre de 5 000 personnes.

Les activités d'exploration sont demeurées fortes principalement dans le nord-est. Actuellement, deux entreprises en sont respectivement au stade du processus de l'évaluation d'impact sur l'environnement et de la demande de baux. Elles devraient entrées en production en 1990. Tous ces élements contribuent à faire des mines une industrie en croissance.

À la lumière de l'importance de l'industrie minière au Nouveau-Brunswick, l'exploration et l'utilisation des gisements de minerais est une priorité pour le gouvernement. Nous entendons encourager l'exploration et la mise en valeur de nos minérais.

Il nous faut mettre au point la technologie pour co-exister avec l'environnement et nous devons développer les compétences pour expliquer ce que représente l'industrie minière. Avec la mise en place de nouvelles politiques et de technologies inédites, nous assisterons au développement du plein potentiel minéral de la province.

Merci.

Le communiqué de presse suivant a été lu par M. Ernest Brooks, géologue d'exploration pour la Brunswick Mining and Smelting Corporation Limited au cours du dîner offert dans le cadre des journées portes ouvertes.

**COMMUNIQUÉ DE PRESSE - 21 novembre 1989**

De récents sondages de recherches au nord de la mine Brunswick n° 12 ont révélé la présence potentielle d'une nouvelle zone sulfurée. Le forage A-248, un forage de surface profond, a permis d'intercepter une masse lenticulaire de minerais sulfuré de 13,4 mètres à près de 2 kilomètres au nord du puits n° 3 à quelque 1 100 mètres de la surface. L'analyse démontre la présence, à 8,5 mètres, de Pb 4,61%, Zn 9,91%, Cu 0,22%, Ag 183,4 g/t, Au 1,65 g/t, suivi d'une section de pyrite de 4,9 mètres contenant Pb 0,55%, Sn 1,50%, Cu 0,18%, Ag 17,5 g/t et Au 0,34 g/t. Le forage de surface visait à poursuivre l'étude d'une intersection massive de pyrite rencontrée lors d'un forage de recherches souterrain à partir du niveau 1 000 à 400 mètres au sud du trou A-248 effectué en septembre.

La présence possible de masses lenticulaires séparées au nord de la mine n° 12 avait été suggérée pour la première fois par M. C. Van Staal lors de son travail de rédaction de thèse à la Brunswick.

Cette découverte repose essentiellement sur des données géologiques, notamment des données de nature structurelle et stratigraphique. Cela permet de démontrer l'engagement de la Brunswick vis-à-vis de l'utilisation d'information recueillie sur la géologie minière dans le cadre de la recherche de nouveaux dépôts sulfurés. Le forage se poursuit actuellement dans cette zone à l'aide d'une foreuse souterraine et d'une foreuse en surface.

Pour de plus amples renseignements, communiquez avec :

M. William M. Luff
Géologue en chef - mines
(506) 547-6064

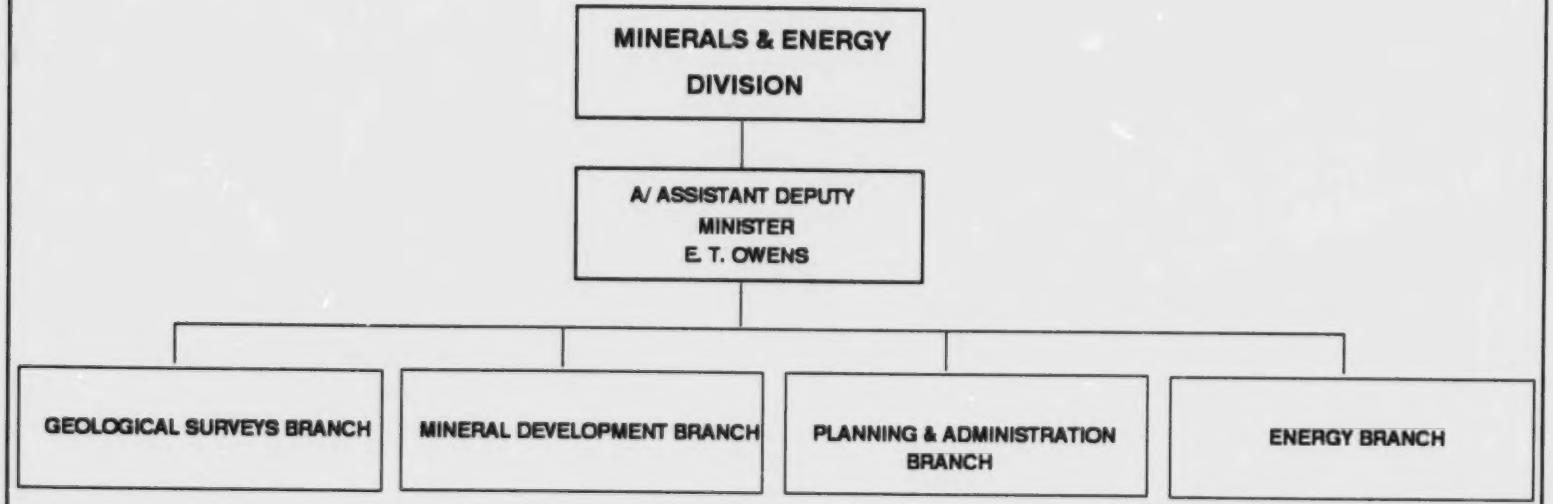
ou

M. Jeff Hussey
Géologue de projet
(506) 546-6671

# PART I

## MINERALS AND ENERGY DIVISION

# New Brunswick Department of Natural Resources & Energy



## ORGANIZATION OF THE MINERALS AND ENERGY DIVISION

### INTRODUCTION

The Minerals and Energy Division of the New Brunswick Department of Natural Resources and Energy is responsible for all mineral and energy resources owned and controlled by the Province. The Division administers, through a number of Acts, all matters related to exploration, development, production, smelting, refining, transportation, and taxation of metallic, nonmetallic, and structural mineral resources.

### GEOLOGICAL SURVEYS BRANCH (Director, J. Leslie Davies)

The Geological Surveys Branch is responsible for the collection, interpretation, dissemination, and management of geoscience data in New Brunswick. The Branch goals are to decipher the regolith and bedrock framework of the Province, and to identify the mineral resource potential of the various geological terranes. Closely related activities include; encouraging mineral exploration, promotion of the mineral industry, and advising government on management of mineral, water, and land resources.

The so-called provincial "A" budget struck for the Geological Surveys Branch in 1989/90 amounts to $1.39 million, down from $1.55 million in 1988/89. Two of the new geoscientist positions provided for in the 1988/89 budget were filled. A.G. Pronk was hired as a geochemist, and W.W. Gardiner was engaged as a mineral deposits geologist. The third position, a geophysicist, was cancelled before it could be filled. The Canada-New Brunswick Mineral Development Agreement is now in its sixth year (carry over). The funds remaining in the Geoscience program are sufficient only for contract salaries and printing costs of final reports and maps.

### MINERAL DEVELOPMENT BRANCH (Director, George Greer)

The Mineral Development Branch consists of 11.0 staff years with an "A" budget of $574 700. The Branch is responsible for the administration of the Mining Act, Quarriable Substances Act, Ownership of Minerals Act, and several policies relating to resource extraction. In addition, various projects under the Canada-New Brunswick Mineral Development Agreement are managed by the unit. The Branch is concerned with the development of the non-renewable resources in the best interest of the citizens of the Province in terms of proper management with respect to maximum return, in-Province processing, mine-site reclamation, and environmental protection. The Branch works closely with the N.B. Department of Environment and other Branches within the N.B. Department of Natural Resources and Energy with respect to land use and environmental impact.

**PLANNING AND ADMINISTRATION BRANCH (Director, Garry MacEwen)**

The Planning and Administration Branch of the Minerals and Energy Division is responsible for providing the Division with economic and financial analysis for input to policy; organizing and co-ordinating public information and education; information assessment, distribution, and administrative support in the area of budgets and financial information. The Branch is also responsible for the development and execution of federal/provincial mineral development agreements.

**ENERGY BRANCH (Director, Don Barnett)**

The Energy Branch has a full-time staff of eight persons with an 'A' budget for 1989-90 of $656 300.00. The goals of the Branch are to identify and promote development of indigenous energy resources, to manage these resources to ensure the maximum contribution to the Province's economy, and to promote energy efficiency and diversity. To meet these goals, the activities of the Branch are directed toward renewable resources, non-renewable resources, and energy conservation. Some of the activities include wood energy demonstration projects, wood energy surveys, alternate energy monitoring, industrial, commercial, institutional, and residential energy conservation, and coal, bituminous shale, and oil and natural gas identification and assessment.

The Energy Branch is responsible for the administration of the Oil and Natural Gas Act, the Bituminous Shale Act, the Underground Storage Act, the Pipeline Act, the Gas Distribution Act, and the Gasoline, Diesel and Home Heating Oil Pricing Act. The Branch is also entrusted with provided energy documentation and advice to the public and private sector.

In 1989-90, the Branch is finalizing its administrative commitments to several Federal/Provincial Mineral Development Agreement projects that focused on oil and natural gas and bituminous shale assessment.

## ORGANISATION DE LA DIVISION DES MINERAUX ET DE L'ENERGIE

### INTRODUCTION

La Division des minéraux et de l'énergie du Ministère des Ressources naturelles et de l'Energie est responsable pour toutes les ressources en minéraux et énergie appartenant à la Province. La Division administre, par plusieurs lois, tout ce qui relèvent de l'exploration, développement, production, raffinage, transport et imposition des ressources minérales métalliques, non-métalliques, et industrielles.

### DIRECTION DES RELEVEES GEOLOGIQUES (Directeur, J. Leslie Davies)

La direction des relevées géologiques est chargée de la collection, l'interprétation, la dissemination, et la gérance de données géo-scientifiques au Nouveau-Brunswick. Les buts de la Section sont une connaissance à fond du sous-sol et de la roche de fond de la Province, et d'éclaircir les possibilités en ressources minérales des régions géologiques diverses. Des activités étroitement associées renferment: la stimulation de l'exploration minière, la promotion de l'industrie minérale, et des conseilles au gouvernement sur le planification des ressources en minéraux, eau, et terrain.

Le soi-disant budget provincial 'A' rédigé pour la service des Relevées Géologiques en 1989/90 se leve à $1.39 millions, moins que le $1.55 millions en 1988/89. Des postes nouveaux, our gens des géosciences, du budget 1988/89 ont été remplies. A.G. Pronk a été engagé comme géochimiste, et W.W. Gardiner comme géologue des gîtes minéraux. Le troisième poste, un géophysicien, a été anulé avant d'être comblé. L'Entente Canada-Nouveau Brunswick de Développement Minier est présentement dans sa sixième année (rapporté). Les fonds restant dans le programme de Géo-science sont adéquats pour seulement les salaires à contrat et les coûts de publication des rapports finaux avec cartes.

### DIRECTION DE L'EXPLOITATION MINERALE (Directeur, George Greer)

La direction de l'Exploitation Minérale a 11.0 années/ effectifs avec un budget "A" de 574 700$. La Service a comme responsibilité l'administration de la Loi Minière, la Loi sur les produits de carrières, et plusieures politiques reliées à l'extraction des ressources. En outre certains projèts sous l'Entente de Développement Minéral Canada/Nouveau-Brunswick sont gérés par elle. Cette Service s'occupe avec la mise en valeur des ressources non-rénouvellable vis à vis le bien-être des citoyens de la province, tenant compte de sa gérance pour une rentabilité maximale, traitement à l'intérieur de la Province, mise à neuf de la site, et la protection de

l'environnement. La direction travaille avec le Département de l'Environnement du Nouveau-Brunswick et avec autres Services du Département des Ressources Naturelles et de l'Energie du Nouveau-Brunswick, en ce qui a trait à l'utilisation de terrain et l'impact sur l'environnement.

**DIRECTION DE PLANIFICATION ET DE L'ADMINISTRATION**
**(Directeur, Garry MacEwen)**

La direction de Planification et de l'Administration de la Division des Minéraux et d'Energie est responsable pour l'analyse économique et financial dont se sert la Division pour établir sa politique, organizer et co-ordonner l'information publique et l'éducation, assessment de l'information, distribution, et support administratif dans des aspects des budgets et information financière. La direction est responsable aussi pour l'élaboration et la mise en exécution d'ententes fédérales/ provinciales sur le développement minéral.

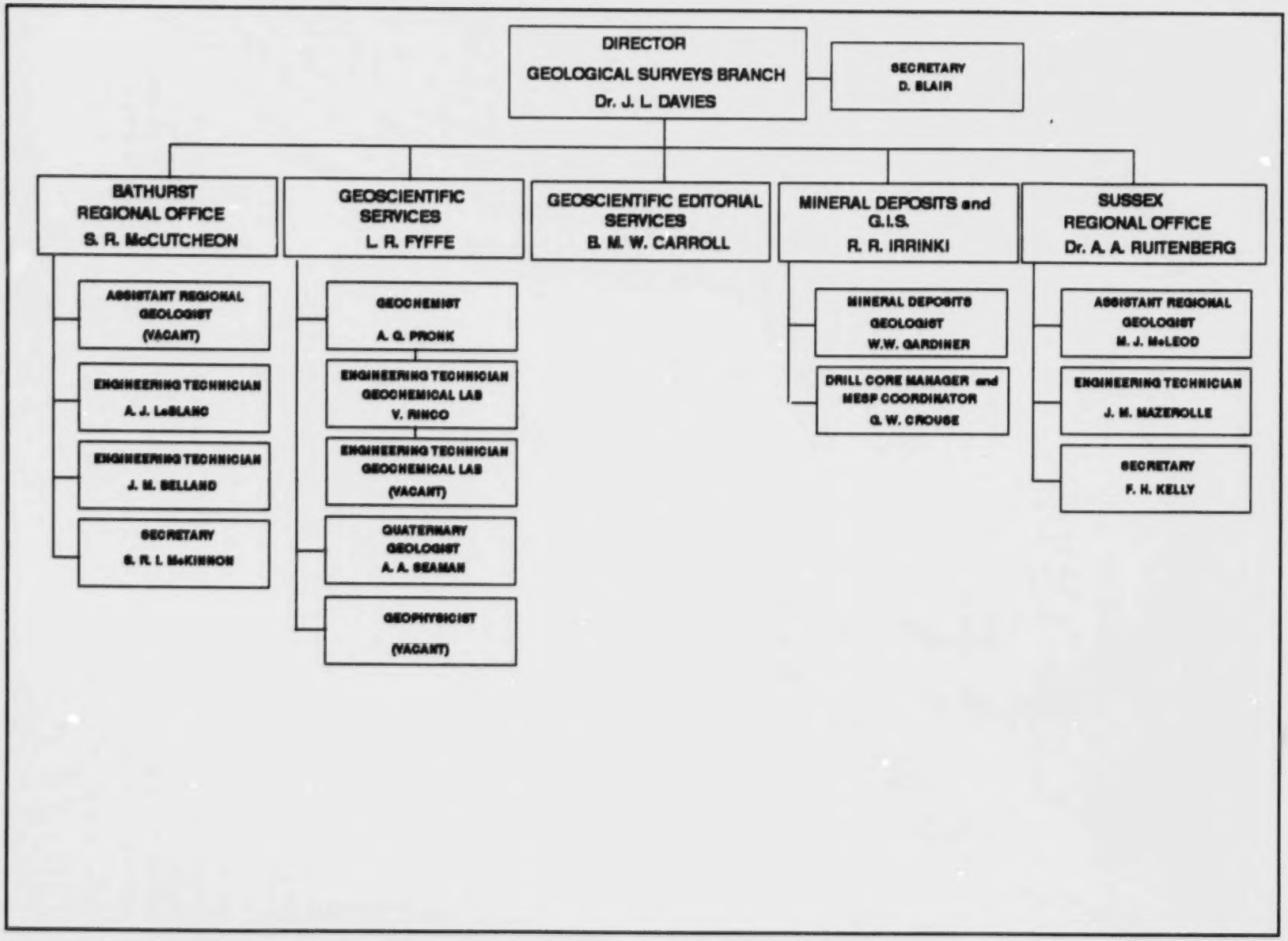
**DIRECTION D'ENERGIE**
**(Directeur, Don Barnett)**

La direction d'Energie a huit personnes à temps plein et un budget "A" pour 1989-90 de 656 300$. Les buts de la Service sont l'identification et la promotion du développement des ressources indigènes d'énergie, à gérer ces ressources pour en tirer une contribution maximale pour l'économie de la Province, et de promouvoir une efficacité et une diversité. Pour rejoindre ces buts, les activités de la Service sont dirigées vers les ressources re-nouvellables, les ressources non-renouvellables, et la conservation de l'énergie. Quelques-unes des activités comprennent des projets de démonstration sur l'énergie tirée du bois, des levés sur cette énergie du bois, l'étude d'autres source d'énergie, la conservation industrielle, commerciale, en institutions et en résidences de l'énergie et l'identification et la validation de l'huile et le gaz naturel.

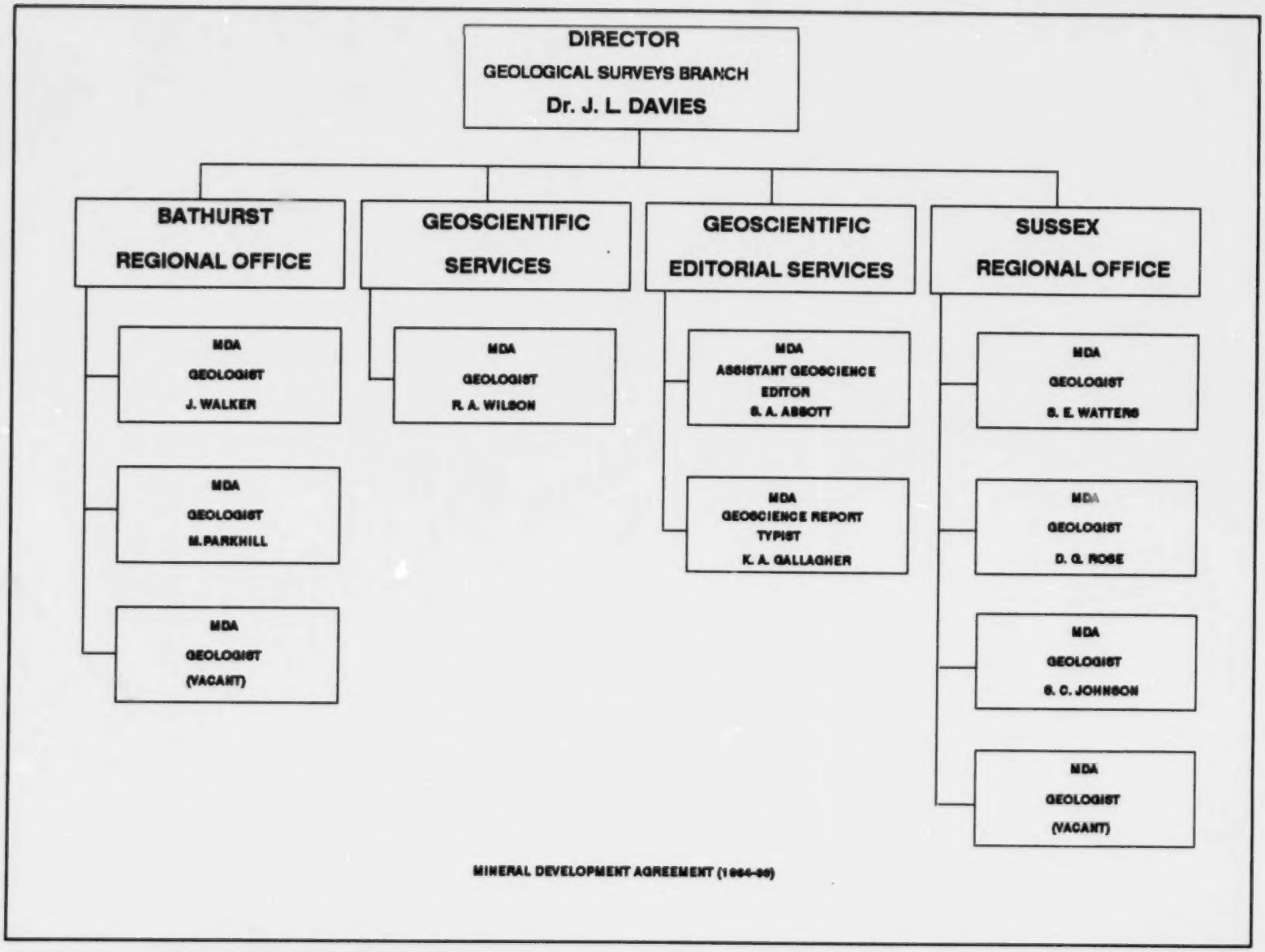
La direction de l'Energie est responsable pour l'administration de la Loi sur le Pétrole et le Gaz naturel, la loi sur les schistes bitumineux, la loi sur l'Entreposage Sous-Terrain, la loi sur les Pipe-lines, la loi sur la Distribution de Gaz, et la loi sur les prix d'essence, huile à diesel, et huile à chauffage de maisons. La Service a aussi le devoir à donner une documentation et des avis sur l'énergie aux secteurs publiques et privées.

En 1989-90, la direction met au point ses obligations administratives à plusieurs projets Fedéraux/Provinciaux d'Ententes en Développement Minéral qui sont axés sur la mise en valeur du pétrole, du gaz naturel et des schistes bitumineux.

## GEOLOGICAL SURVEYS BRANCH




**Organization chart for Geological Surveys Branch - permanent staff**




**Organization chart for Geological Surveys Branch - MDA contract personnel**

**GEOLOGICAL SURVEYS BRANCH**

**GEOSCIENTIFIC SERVICES SECTION**

## ACTIVITIES OF THE GEOSCIENTIFIC SERVICES SECTION

L.R. Fyffe, Senior Geologist

The Geoscientific Services staff, located at the Hugh John Flemming Centre in Fredericton, consists of Les Fyffe (Senior Geologist), Allen Seaman (Quaternary Geologist), Toon Pronk (Geochemist), and Valeria Rinco (Geochemical Analyst). Reg Wilson (Project Geologist) carried out a contract mapping project under the Canada-New Brunswick MDA.

Reg Wilson mapped the bedrock geology of Nepisiguit Lakes (21 O/7W) map area and completed mapping in the Riley Brook area (21 O/3E and 21 O/2W) begun in 1988. The surveyed area is underlain by Early Devonian volcanic and sedimentary rocks of the Tobique Group. Trace-element analyses indicate that the volcanics are a bimodal suite of basalts and rhyolites deposited within a continental-rift setting. Epithermal alteration zones within the felsic volcanic rocks contain lead-zinc mineralization associated with elevated gold values.

Les Fyffe mapped the bedrock geology of the Moores Mills area in Charlotte County (parts of 21 G/3 and 21 G/6), southwestern New Brunswick on a 1:20 000 scale. The survey completes coverage between Rollingdam and the Maine border. A fossil locality discovered during this investigation required significant stratigraphic revision of the Cookson Group. In addition, a major fault was found to separate the Ordovician Cookson Group from the Silurian Flume Ridge Formation to the north. This fault zone contains quartz-vein swarms, quartz-feldspar porphyry dykes and apparently localizes emplacement of the Mount Pleasant caldera.

Liz MacLellan has published a paper on the Burnthill tin-tungsten deposits in the Hayesville map area (21 J/10) and has finalized an MDA report on the geology of the Burnthill Brook area. Digital LANDSAT imagery maps of the area were prepared by Geodat Information Services Ltd.

Toon Pronk and Mike Parkhill mapped the surficial deposits and sampled tills in the Nepisiguit Lakes map area (21 O/7), and collected stream and water samples in the Canterbury map area (21 G/14). Approximately 1000 till samples and 520 drill-core samples were analysed for Cu, Pb, Zn, Ag, Fe, Mn, Co, Ni, Mo, and W by Valeria Rinco at our geochemical laboratory.

Allen Seaman conducted a regional study of glacial deposits in southwestern New Brunswick (NTS 1:50 000-scale map sheets 21 G/3, 6, 7, 10 to 16; and Campobello Island, NTS 21 B/15), expanding on the work begun in 1988. This investigation involved the measurement of glacial striae patterns on bedrock surfaces and the determination of their chronological

cross-cutting relationships, measurement of till fabrics, and sampling of tills for geochemical and lithological analysis.

Christopher Bianchi, an undergraduate geology student at the University of New Brunswick, Fredericton, undertook detailed surficial mapping and geochemical sampling (150 $km^2$) in the vicinity of the Mount Pleasant Caldera (parts of NTS 21 G/7 and G/10). An airborne geophysical survey of the caldera area by the Geological Survey of Canada in 1989 identified a north-south-trending radioactivity low that has no correlation with topography or known bedrock structures. The study area covers this negative anomaly and the adjacent terrain. The purpose of the investigation is to determine whether this feature is caused by the surficial materials, and to examine the implications with respect to drift prospecting.

Marc Foisy, a graduate student at l'Université du Québec à Montréal, studied the glacial deposits and glacial striae patterns of the Waterford (NTS 21 H/11) and Salmon River (NTS 21 H/6) map areas in southeastern New Brunswick. Till samples were taken at a reconnaissance level for geochemical analysis.

The Bibliography of New Brunswick Geology (1839-1988) compiled by Les Fyffe and Diane Blair is now available as Geoscience Report 89-3 and on a computer database. The bibliography includes references to the geoscientific literature accumulated over the past 150 years, beginning in 1839 when the Provincial government issued Gesner's first of four reports on the geology of New Brunswick. It supersedes a compilation published by the New Brunswick Research and Productivity Council in 1969. The 2800 entries in this updated version include approximately 1400 references from the RPC edition, as well as references to the post-1969 geological literature. Federal and provincial government reports, together with papers from geoscientific and technical journals comprise the majority of entries, but theses, field guides, consultant reports, and articles from books and newspapers are also listed. Each entry presents the following information: author(s), year of publication, title of article, source, and page numbers.

Les Fyffe presented a talk in February, 1989, at the Atlantic Geoscience Society Colloquium in Amherst, Nova Scotia, entitled "Tectonic significance of Ordovician basalts in the St. Croix Terrane of coastal Maine and New Brunswick." A talk entitled "The St. Croix Terrane of southwestern New Brunswick: Proposed relationships to Gander and Avalon terranes based on new palaeontological, structural, and geochemical evidence." was given by Les Fyffe at the Lithoprobe East Transect Meeting held in St. John's, Newfoundland on October 19 and 20, 1989. Other talks given at this meeting described the recent deep seismic results from the Newfoundland on-land transect and related geological and geochemical work. The delineation of fault structures by a high-resolution seismic survey in the

Buchans area was of particular interest since this method may have applicability in the Bathurst-Newcastle Mining Camp.

A poster display was exhibited by Reg Wilson at the Prospectors and Developers Association Annual Meeting in Toronto, and at the Geological Association of Canada/ Mineralogical Association of Canada Joint Annual Meeting in Montreal, 1989. The title of this display was, "Preliminary geology and lithogeochemistry of selected rock samples from the Riley Brook area, New Brunswick."

Talk entitled, "The Appalachian glacier complex: An analog to the Cordilleran ice complex?" and "Late Wisconsinian glaciation and deglaciation of the St. Croix Highlands area, southwestern New Brunswick." were given by Toon Pronk and Allen Seaman, respectively, at the Canqua 1989 Conference, Edmonton, Alberta. Toon Pronk and Mike Parkhill presented a poster session at the Atlantic Geoscience Society - 1989 Colloquium in Amherst, Nova Scotia, entitled "Why Laurentide ice indicators are absent in the Baie des Chaleurs region, northern New Brunswick."

Papers describing the geology of the Dunnage and Gander zones in New Brunswick by Cees van Staal and Les Fyffe, and the tectonic setting of granitoid-related mineral deposits in New Brunswick by Art Ruitenberg and Les Fyffe, have been prepared for a DNAG (Decade in North American Geology) volume on the Appalachian Orogen. A summary of the chemistry of volcanic rocks in New Brunswick, Nova Scotia, and the Eastern Townships of Quebec, is being prepared by Les Fyffe and Sandra Barr for the same volume.

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Les cadres des Services Géoscientifiques se trouvant au Centre Hugh John Flemming à Frédericton, sont Les Fyffe (géoloque sénior), Allen Seaman (géologue pour la Quaternaire), Toon Pronk (géochemiste), Valeria Rinco (analyste géochimique), et Reg Wilson (EDM, géologue de projet).

Outre les activités normales de effectifs réguliers plusieurs projets ont été menés par des gens à contrat et saisoniers suivant l'entente EDM Canada/Nouveau-Brunswick. Toon Pronk a fait une levée des sédiments à ruisseau et de l'eau de la région de Canterbury (feuille 21 G/14), et Mike Parkhill a supervisé la cartographie et l'échantillonage de la moraine de la région de Lacs Nepisiguit (feuille 21 0/7). Reg Wilson a cartographié le socle des feuilles Riley Brook (21 0/3) et Lacs Nepisiguits (21 0/7). Liz MacLellan a eu publié un papier sur les gîtes d'étain-tungstène de la région de la carte Hayesville (21 J/10) et a terminé un rapport EDM sur la géologie de la région Ruisseau Burnthill.

Les Fyffe a cartographié et révisé la stratigraphie de la région de Moores Mills dans le comte-de Charlotte (des parties de 21 G/3 et 21 G/6). Des analyses géochimiques faites par Valeria Rinco ont compris 540 échantillons de carôts de sondages, et à peu près 1000 échantillons d'échantillons de moraine analysés pour Cu, Pb, Zn, Ag, Fe, Mn, Co, et Ni.

Un projet de géologie du Quaternaire, effectué par Al Seaman, a été l'étude des caractéristiques glaciaires et des dépôts glaciaires dans le sud-ouest du Nouveau-Brunswick (spécifiquement les cartes SNRC à l'échelle de 1:50 000 - 21 G/3, 6, 7, 10 à 16; et l'île Campobello, 21 B/15). Ce travail avait débuté l'année passée. Il inclus les mesures des systèmes de stries glaciaires sur des affleurements rocheux et, dans la mesure du possible, la détermination de leurs rapports chronologiques; les mesures des trames de till; et l'échantillonnage des tills pour des analyses géochimiques et lithologiques.

Un deuxième projet, effectué par Christopher Bianchi, étudiant de géologie à l'Université du Nouveau-Brunswick à Fredericton, a été la cartographie en détail de la géologie de la surface, et l'échantillonnage du till pour des analyses géochimiques, sur une étendue de presque 150 $km^2$ dans la région de la caldeira de Mount Pleasant (parties des régions cartographiques 21 G/7 et G/10). Un levé géophysique aéroporté de la région de la caldeira par la Commission géologique du Canada en 1989 a identifié une anomalie radioactive négative orienté nord-sud, qui n'est pas reliée à la topographie ou à la structure connue du soubassement rocheux. La région à l'étude inclus cette anomalie et le terrain adjacent. Le but de cette étude a été de determiner si cette anomalie est due aux dépôts de surface et, si c'est le cas, de déterminer les implications quant à la prospection.

Un troisième projet, effectué par Marc Foisy, étudiant en maîtrise à l'Université du Québec à Montréal, a été l'étude des dépôts glaciaires et des systèmes de stries glaciaires dans les régions cartographiques Waterford (SNRC 21 H/11) et Salmon River (SNRC 21 H/6), dans le sud-est du Nouveau-Brunswick. Cette étude a inclus un programme de reconnaissance d'échantillonnage du till pour des analyses géochimiques.

# TOBIQUE PROJECT - VICTORIA, RESTIGOUCHE, AND NORTHUMBERLAND COUNTIES, NEW BRUNSWICK (MDA)

R.A. Wilson, Project Geologist

The Riley Brook and Nepisiguit Lakes map areas are underlain by the Lower Devonian Tobique Group, consisting of variable proportions of mafic and felsic volcanic and sedimentary rocks.

Three major sequences can be recognized in the Riley Brook area, each apparently initiated by mafic volcanism, followed by felsic volcanism. Felsic volcanic rocks are massive, porphyritic, or flow-banded lavas containing textures reflecting an originally glassy state. The abundance of glassy lavas, associated with pillow basalts and marine sedimentary rocks, is interpreted to record the widespread growth of subaqueous lava domes. Local emergence is suggested by units of subaerial lapilli tuff.

In the Nepisiguit Lakes area, felsic volcanic rocks are mainly subaerial crystal and lithic tuffs, with minor flow-banded rhyolite. These rocks interfinger with an assemblage of volcaniclastics, debris flows, and tuffs interpreted as subaqueous epiclastic facies derived from contemporaneous subaerial volcanism. Mafic volcanic rocks occur only in minor amounts.

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Les zones cartographiées de Riley Brook et des lacs Nepisiguit recouvrent le groupe Tobique du début du dévonien consistant de proportions variables de roches volcaniques mafiques, felsiques et sédimentaires.

On reconnait trois séquences principales dans la région de Riley Brook, chacune apparemment formée par un volcanisme mafique suivi d'un volcanisme felsique. Les roches volcaniques felsiques sont massives, porphyriques, ou sous forme de laves litées renfermant des textures qui reflètent un état vitreux originel. L'abondance de laves vitreuses, associées à des roches basaltiques et sédimentaires marines, est interprétée comme un signe de la croissance répandue de dômes de laves subaquatiques. La présence d'ensembles de conglomérats volcaniques à lapilli subaériens suggère une émersion locale.

Dans la région des lacs Nepisiguit, les roches volcaniques felsiques sont principalement du crystal subaérien et des tufs volcaniques avec un peu de rhyolite litée. Ces roches sont en interdigitation avec un ensemble de roches volcaniques, de coulées boueuses et de tufs interprété comme un facies détritique subaqueux provenant d'un volcanisme subaérien contemporain. Les roches volcaniques mafiques ne sont présentes qu'en faible quantité.

## INTRODUCTION

Geological mapping and mineral potential evaluation of the Lower Devonian Tobique Group in northwestern New Brunswick continued during the 1989 field season. The Tobique Group consists of a thick volcano-sedimentary sequence juxtaposed by major faults against Cambro-Ordovician rocks of the Miramichi Terrane to the east and Ordovician to Silurian calcareous and noncalcareous deep basinal flysch to the west. Upon completion of the field program initiated in 1988 in the Riley Brook area

(NTS 21 O/3E, part of NTS 21 O/2W), mapping was undertaken in the Nepisiguit Lakes area (NTS 21 O/7W).

**RILEY BROOK AREA**

General Geology: The Riley Brook area is characterized by an interbedded succession of bimodal felsic and mafic volcanic rocks and sedimentary rocks (Figure 1). In terms of area, felsic and mafic volcanic rocks are approximately equally represented, whereas sedimentary rocks are more abundant, although typically poorly exposed. The distribution of volcanic rocks is uneven: the proportion of volcanic rocks is greatest and exceeds that of sedimentary rocks in the southern and western portions of the map area, but rapidly becomes less abundant to the north and east. Volcanic rocks can be assigned to three major suites, separated by narrow continuous belts of sedimentary rocks. From east to west, and oldest to youngest, these are: 1) the Colters Mountain-River Dee suite; 2) the Stewart Brook-Black Mountains suite; and 3) the Blue Mountain-Riley Brook suite.

Colters Mountain-River Dee Suite: The Colters Mountain-River Dee suite, which is in fault contact with Lower Palaeozoic metasedimentary and plutonic rocks of the Miramichi Terrane, comprises roughly equal proportions of mafic and felsic volcanic rocks although sedimentary rocks are generally predominant and become more abundant from south to north. Thin units of flow-banded rhyolite, lapilli tuff, and minor mafic volcanic rocks in the northeast corner of the map area represent a continuation of this belt. Mafic rocks include massive to vesicular or porphyritic basalts and basaltic lapilli tuffs. Felsic rocks are typically aphanitic, massive to flow-banded rhyolites displaying spherulitic, perlitic, and locally porphyritic textures, and minor autoclastic breccia, interpreted as originally glassy lavas forming submarine domes. Crystal-lithic lapilli tuffs exposed in the vicinity of Shingle Gulch are presumably subaerial and represent local emergence of the volcanic pile.

The oldest rocks of the Tobique Group are exposed near the western margin of NTS 21 O/2. These consist of polymictic conglomerates containing numerous pebbles and cobbles of quartzite, schist, and quartz, whose provenance is clearly in Cambro-Ordovician rocks of the Tetagouche Group to the east. Therefore, an unconformity existed here before movement along the Portage Lakes-Serpentine River fault system locally removed basal conglomerate beds from the record, and in places juxtaposed felsic or mafic volcanic rocks against the Miramichi Terrane.

Stewart Brook-Black Mountains Suite: The Stewart Brook-Black Mountains suite occupies the central portion of the map area, between two narrow, apparent synclines occupied by grey to green siltstone and fine-grained sandstone. This suite is composed primarily of two large masses of felsic volcanic rocks underlying the Gulquac Mountains and Black Mountains, with

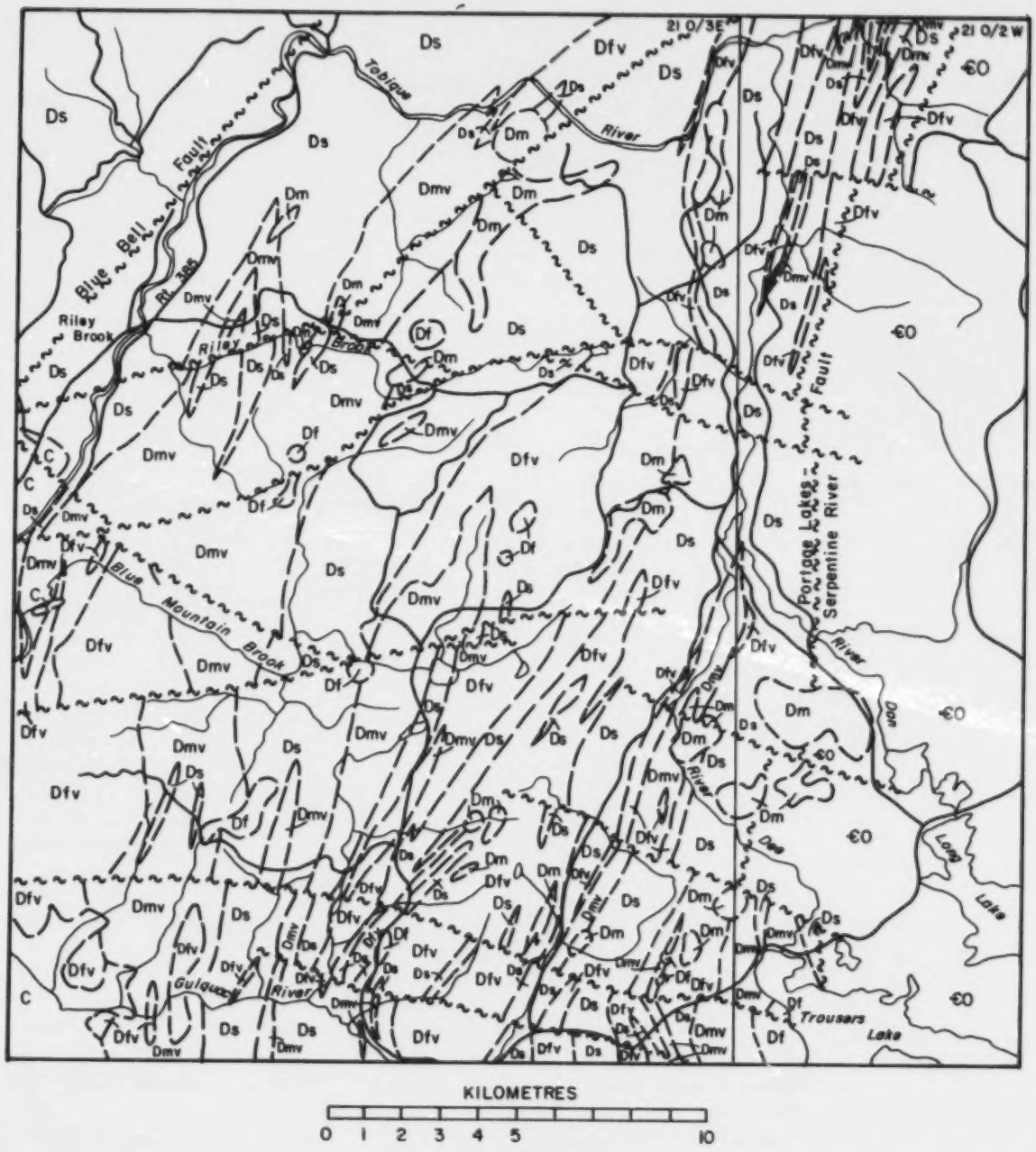



FIGURE 1. Bedrock geology of Riley Brook area, NTS 21 O/3E and part of 21 O/2W.

CARBONIFEROUS

C — *Red sandstone, shale, conglomerate*

DEVONIAN

Dm — *Mafic intrusive rocks*

Df — *Felsic intrusive rocks*

LOWER DEVONIAN - Tobique Group

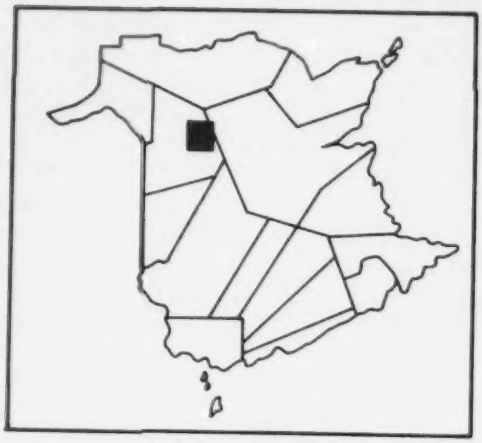
Dmv — *Mafic volcanic rocks*

Dfv — *Felsic volcanic rocks*

Ds — *Sedimentary rocks*

CAMBRO-ORDOVICIAN - Tetagouche Group

€O — *Quartzite, schist*



MAP LOCATION

lesser pillow basalt and interbedded dark, fine-grained sedimentary rocks.

Mafic rocks are typically grey to green, massive to vesicular pillow basalt and rare hyaloclastic tuff, reflecting submarine conditions. Felsic rocks underlying the Gulquac Mountains are typically massive, aphanitic to K-spar-phyric rhyolites and minor associated hyaloclastic and autoclastic rocks derived from submarine lava-dome growth. Flow-banding is developed only locally. Apparent pyroclastic textures in many of these rocks are produced by inhomogenous devitrification, perlitic fracture, and subsequent recrystallization or hydrothermal alteration of glassy lavas and autobreccias (cf. Allen 1988). Although it is possible that some true pyroclastics may be present, the close association of felsic volcanic rocks with pillow basalts and shelf-type quartzose sedimentary rocks, suggests that subaerial eruption was rare.

Most felsic rocks of the Black Mountains were emplaced in a similar environment. The most widespread rock type is a grey, green, or pink-brown, massive and homogenous, typically K-spar-phyric rhyolite, again forming a submarine lava-dome. Although classical spherulitic textures are almost completely absent due to subsequent recrystallization, local relict perlitic fractures indicate originally glassy states. Subtle primary layering is commonly present; however, flow-banded rhyolite is relatively rare. The local occurrence of quartz-filled vesicles, typically drawn out during flow, attests to eruption under high hydrostatic pressure, inhibiting vesiculation. The western portion of the Black Mountains felsic suite, extending from

Riley Lake southwest to Haystack Mountain, consists for the most part of lapilli tuffs, indicating that subaerial deposition prevailed here; it is likely that these pyroclastic rocks were deposited as growth of the lava dome led to emergence of the volcanic pile above sea level. Lapilli tuffs consist of cognate and juvenile lithic fragments, pumice, and fiamme in a vitric groundmass containing abundant glass shards and spicules, suggesting Plinian or sub-Plinian explosive volcanism.

Blue Mountain-Riley Brook Suite: The Blue Mountain-Riley Brook suite is thickest in the southwestern portion of the map area and gradually pinches out in a north-northeasterly direction. Mafic volcanic rocks are most abundant, and appear to envelop felsic volcanic rocks underlying Blue Mountain. At the northeastern extent of this belt, mafic volcanic rocks apparently pinch out quickly near the Tobique River, to be replaced by felsic pyroclastic deposits underlying Serpentine Mountain; unfortunately, the nature of this transition is obscured by a gabbroic stock. Mafic volcanic rocks include fine-grained, grey to green, locally vesicular or porphyritic massive and pillowed basalts, typically interbedded with lesser amounts of dark grey siltstone and fine-grained sandstone. Narrow horizons of basaltic lapilli tuff are present but not common; hyaloclastic rocks were not observed.

Blue Mountain felsic volcanic rocks are typically red-brown or maroon, hematitic, porphyritic, flow-banded, and often spherulitic rhyolite. Devitrification of originally glassy lava occurred inhomogenously, and in many flow-banded rocks, spherulitic growth has been controlled by the primary layering. Perlitic textures are rare. Lenticular quartz±sericite-filled vesicles are common and indicate drawing out of gas bubbles during (subaqueous) flow. Minor volcaniclastic debris flows and vitric lapilli tuffs attest to local subaerial conditions. The Blue Mountain felsic suite, like those discussed previously, is the product of a subaqueous dome-building event, though possibly at shallower depths, based on the absence of interbedded sedimentary rocks, and the presence of debris flows and local pyroclastic rocks. Almost all felsic rocks (and many of the enclosing basalts) contain abundant hematite "dust", and often discrete grains of rusty to specular hematite, imparting the characteristic colour of these rocks. It is concluded that oxidizing fluids must have invaded a large volume of volcanic rock at some point subsequent to emplacement.

The Serpentine Mountain felsic volcanic rocks include lithic and lithic-crystal lapilli tuffs, with lesser massive and flow-banded aphanitic rhyolite. Pyroclastic rocks are observed in contact with thinly bedded siltstones, and must therefore have been deposited in a shallow-water, near-shore environment.

Mafic intrusive rocks are very common in the Riley Brook map area. Dykes and sills are ubiquitous, whereas plutonic

rocks are especially abundant near the Portage Lakes-Serpentine River Fault, and near the Tobique River. Felsic intrusive bodies occur in circular to elongated ovoid shapes, suggestive of subvolcanic necks and plugs. They are, therefore, assumed to represent the magmatic source of the felsic volcanic piles, which is borne out by the similarity of their trace-element and REE patterns.

**Stratigraphy**: Volcanic cycles appear to have been characterized by dominantly mafic followed by dominantly felsic volcanism. Within the Colters Mountain-River Dee suite (southeast corner of the map area), mafic volcanic rocks form the lowermost unit of a west-dipping sequence adjacent to the Miramichi Terrane. In the Stewart Brook-Black Mountains suite, pillow basalts occupy the core of an anticline which divides the overlying Black Mountain massif into two "arms". Within the Blue Mountain-Riley Brook suite, felsic volcanic rocks were interpreted to post-date spatially associated pillow basalts, since felsic plugs interpreted as conduits for felsic volcanism intrude the mafic volcanic rocks.

**Chemistry**: The chemistry of volcanic rocks in the Riley Brook map area is characteristic of Siluro-Devonian volcanic rocks elsewhere in northern and western New Brunswick (Dostal et al. 1989), and consist of bimodal suites of basalts and rhyolites (<52% $SiO_2$, >70% $SiO_2$, anhydrous, respectively). Mafic rocks are subalkaline and show a within-plate affinity on discrimination diagrams used to infer tectonic setting. Trace-element and REE patterns resemble those of continental tholeiites, with relatively unfractionated REE and La/Yb ratios ranging from 3 to 9. Felsic rocks show a pattern of increasing alkalinity from east to west (oldest to youngest), characterized by generally increasing Nb/Y and $Zr/TiO_2$ ratios. Felsic rocks from Blue Mountain plot in the peralkaline field on a Nb/Y versus $Zr/TiO_2$ diagram. The Black Mountains and Blue Mountain suites are both peralkaline according to the classification of Leat et al. (1986), based on average Zr contents of 653 and 726 ppm, respectively. Similar values are obtained from the assumed intrusive counterparts of these rocks: Zr contents in the Haystack Mountain plug and in the felsic intrusion just east of Blue Mountain are 769 and 646 ppm, respectively. In addition, riebeckite, a sodic amphibole often found in alkaline igneous rocks, was identified in thin section from a sample of the latter intrusion. REE patterns in the felsic volcanic rocks are similar to those of the mafic volcanic rocks, except for higher absolute concentrations and a prominent negative Eu anomaly in the felsic rocks.

**Depositional Environment**: The volcano-sedimentary sequence in the Riley Brook area is interpreted to have been deposited in a continental margin marine environment (with local emergent volcanic islands), in an extensional tectonic regime. This interpretation is consistent with the bimodal and within-plate geochemical affinity of the volcanic rocks, the occurrence of

peralkaline rhyolites, and the presence of a number of volcanic centres.

Economic Geology: A number of base-metal occurrences and lithogeochemical anomalies characteristic of epithermal-style alteration are present in the Riley Brook area. Lead-zinc mineralization is present at the Sewell Brook, Riley Lake, and Shingle Gulch occurrences, within silicified and brecciated felsic volcanic rocks (Wilson 1988). This mineralization is accompanied by modest Au values (40-170 ppb), and significant amounts of the "epithermal pathfinders", As, Sb, Hg, and Tl. Anomalous values of the "pathfinder" elements are also found in a number of other localities, hosted by felsic or mafic volcanic rocks or by sedimentary rocks, typically accompanied by varying degrees of leaching, silicification, and/or hematitization. Alteration in mafic volcanic and sedimentary rocks on and near Riley Brook, just east of the village of Riley Brook, is strikingly similar to that observed at Corona Corporation's Rocky Brook occurrence.

The submarine depositional setting proposed for most of the rocks in the Riley Brook map area may preclude possible occurrences of the classical hot-spring type, which are typically formed in terrestrial environments. On the other hand, a submarine volcanic environment is much more prospective of volcanogenic massive sulphide deposits. The glassy lavas comprising the various submarine domes in the map area have undergone devitrification, perlitic fracture, and/or autobrecciation, all of which increase porosity and permit extensive circulation of hydrothermal solutions derived from proximal volcanic centres. Local silicification and widespread sericite/chlorite alteration in felsic volcanic rocks in the Riley Brook map area provides evidence of pervasive hydrothermal activity. Hydrothermal effects are further reflected by alkali mobility, i.e., many of these rocks show an extreme range of Na/K ratios. Alkali mobility is particularly evident in the Blue Mountain area, where oxidizing solutions producing high hematite contents may also have mobilized and redeposited gold.

## NEPISIGUIT LAKES AREA

The geology of the Nepisiguit Lakes area (NTS 21 O/7W) is generally similar to that of the Riley Brook area, representing a northeastward extension of the succession of interbedded volcanic and sedimentary rocks of the Tobique Group. Chemical analyses and petrographic studies are not yet available as field work in this area began only in July of 1989. The geological map (Figure 2) should, therefore, be considered preliminary. However, several general comments can be made on the geology, based on field observations, and how it differs from that of the Riley Brook area.

Mafic volcanic rocks are not nearly as abundant as in the Riley Brook area, and underlie only about 2% of the total area;

felsic volcanic rocks, on the other hand, comprise an equal or greater proportion of bedrock lithologies compared to Riley Brook. Most felsic volcanic rocks form part of a single voluminous suite underlying the Mount Carleton massif. Underscoring the paucity of mafic volcanic rocks, mafic intrusive rocks are virtually absent except for local dykes and one mafic stock in the northeast corner of the map area. Only a few felsic stocks or plugs were recognized. Most are fine-grained porphyritic felsites interpreted as subvolcanic conduits for the extrusive rocks. Small circular and ovoid intrusions are found in the northeast corner of the map area, whereas a felsic intrusive body at Nictau Lake, west of the Mount Carleton massif, is very elongate, and perhaps reflects fissure-type eruption.

The vast majority of felsic volcanic rocks have been identified in the field as crystal tuffs, and crystal-lithic or lithic-crystal lapilli tuffs. Flow-banded rhyolites are common only in the southeast corner of the map area adjacent to the Portage Lakes-Serpentine River Fault. Thus, subaerial deposition appears to be the rule in the Nepisiguit Lakes area, as opposed to subaqueous deposition at Riley Brook. Herein lies the apparent reason for the common occurrence of a sequence of epiclastic rocks not seen in the Riley Brook area. Intimately interbedded volcaniclastic sandstones and siltstones, lithic wackes or sandstones, debris flows, and waterlain pyroclastic flows are interpreted to represent detritus and distal-facies pyroclastics derived form a rapidly growing subaerial volcanic edifice. These lithologies are, for unknown reasons, found only on the north side of the Mount Carleton massif. Additional study may succeed in determining the paleogeographic basis for the distribution of these rocks.

Compared to the Riley Brook area, mineral occurrences are uncommon in the Nepisiguit Lakes area. Except for minor malachite noted in an outcrop of mafic volcanic rocks in the northeastern portion of the map area, pyrite was the only mineralization observed, albeit rarely in excess of 1 to 2%. Few indications of possible epithermal-style alteration were noted. A number of samples have nonetheless been sent for multi-element lithogeochemical analysis, although results have not been received as of this writing.

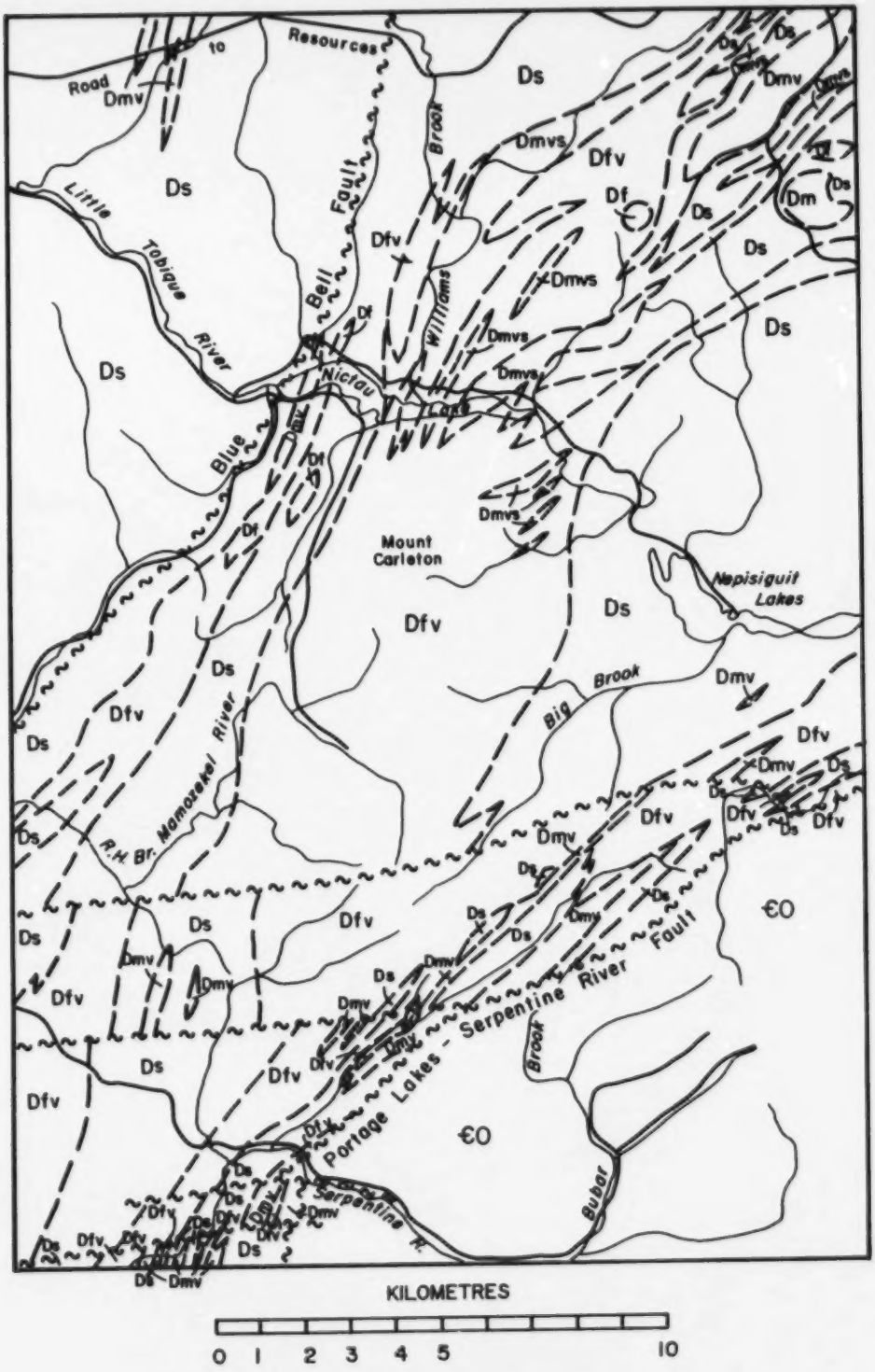



FIGURE 2. Preliminary geological map of Nepisiguit Lakes (west) map area, NTS 21 O/7W.

DEVONIAN

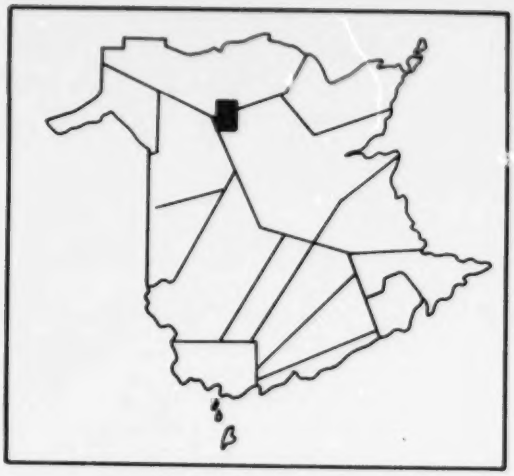
| | |
|---|---|
| Dm | *Mafic intrusive rocks* |
| Df | *Felsic intrusive rocks* |

LOWER DEVONIAN - **Tobique Group**

| | |
|---|---|
| Dmv | *Mafic volcanic rocks* |
| Dmvs | *Volcaniclastic sediments, debris flows, water-lain tuffs and pyroclastics* |
| Dfs | *Felsic volcanic rocks* |
| Ds | *Sedimentary rocks* |

CAMBRO-ORDOVICIAN - **Tetagouche Group**

| | |
|---|---|
| €O | *Quartzite, schist* |



MAP LOCATION

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# BEDROCK GEOLOGY OF THE MOORES MILLS AREA, CHARLOTTE COUNTY, NEW BRUNSWICK

L.R. Fyffe, Senior Geologist

A geological survey was conducted in southwestern New Brunswick in order to investigate the relationships between various Palaeozoic rock units in the region.

The Cookson Group is divided into three formations as recognized in the adjacent area of Maine. However, the stratigraphic order of these formations is revised based on the discovery of a new fossil locality. From the base upward, the Ordovician Cookson Group comprises the Calais, Woodland, and Kendall Mountain formations.

The Digdeguash Formation, previously considered to be Silurian in age, is now assigned to the Cookson Group. Primary sedimentary structures in the Digdeguash Formation indicate that it gradationally underlies the Kendall Mountain Formation and represents a facies equivalent of the Woodland Formation.

The contact between the Digdeguash Formation and Silurian Flume Ridge Formation, previously interpreted to be gradational, is a major fault (southeastward-directed thrust?). A system of quartz veins along this fault zone is a potential host for epithermal mineralization.

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Une étude géologique a été menée dans le sud-ouest du Nouveau-Brunswick afin d'évaluer les rapports entre les diverses unités rocheuses paléozoiques de la région.

Le groupe Cookson est divisé en trois formations similaires à celles que l'on retrouve dans la région adjacente du Maine. Cependant l'ordre stratigraphique de ces formations a été revu en se basant sur la découverte d'un nouvel emplacement de fossiles. De bas en haut, le groupe ordovicien de Cookson comprend les formations Calais, Woodland et Kendall Mountain.

La formation Digdeguash, antérieurement considérée comme étant de l'époque silurienne est maintenant intégrée au groupe Cookson. Les structures primaires sédimentaires de la formation Digdequash indiquent qu'elle s'incline graduellement par rapport à la formation Kendall Mountain et représente un facies similaire à celui de la formation Woodland.

La zone de contact entre la formation Digdeguash et la formation silurienne Flume Ridge, antérieurement considérée comme étant graduelle est en fait une faille importante (poussée orientée vers le sud-est?). Un système de veines de quartz le long de cette zone de failles est un hôte en puissance pour une minéralisation épithermique.

## INTRODUCTION

A largely unmapped portion of the St. Croix Terrane (Figure 3), lying between the Canada-U.S.A. border and Moores Mills to the north of St. Stephen (Figure 4), was surveyed in the summer of 1989 in order to tie together the work of Ludman (1987) in Maine and that of Ruitenberg (1967) in New Brunswick. Substantial revisions to previously reported stratigraphic relationships were required as a result of this investigation. These changes also necessitated a re-evaluation of comparisons made with the Miramichi and Avalon terranes.

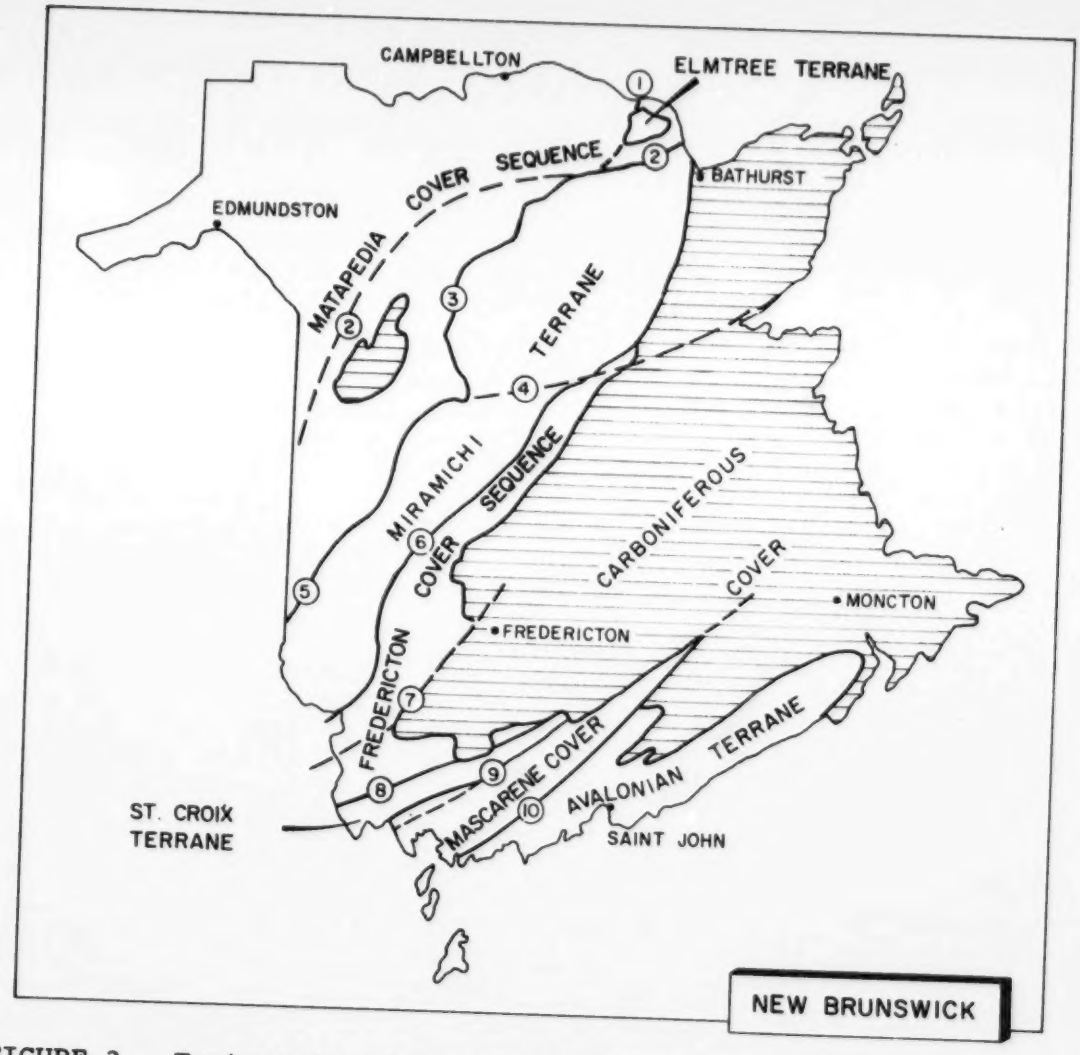


FIGURE 3. Tectonostratigraphic terranes of New Brunswick (after Fyffe and Fricker 1987).
Faults: 1. Jacquet River, 2. Rocky Brook-Millstream, 3. Portage Lakes-Serpentine River, 4. Catamaran, 5. Woodstock, 6. Bamford Brook-Hainesville, 7. Fredericton, 8. Basswood Ridge-Cox Brook, 9. Ketchum Brook, and 10. Belleisle-Wheaton Brook.

**STRATIGRAPHY**

Formational divisions within the Cookson Group of Maine can be recognized in New Brunswick. However, a new fossil discovery indicates that the stratigraphic order is the reverse of that suggested by Ludman (1987). The Calais Formation, now known to be the lowermost unit of the Cookson Group (Figure 4), can be traced from its type locality on the St. Croix River at the border towns of Calais and St. Stephen as far eastward as Oak Bay. The formation comprises black carbonaceous slate inter-

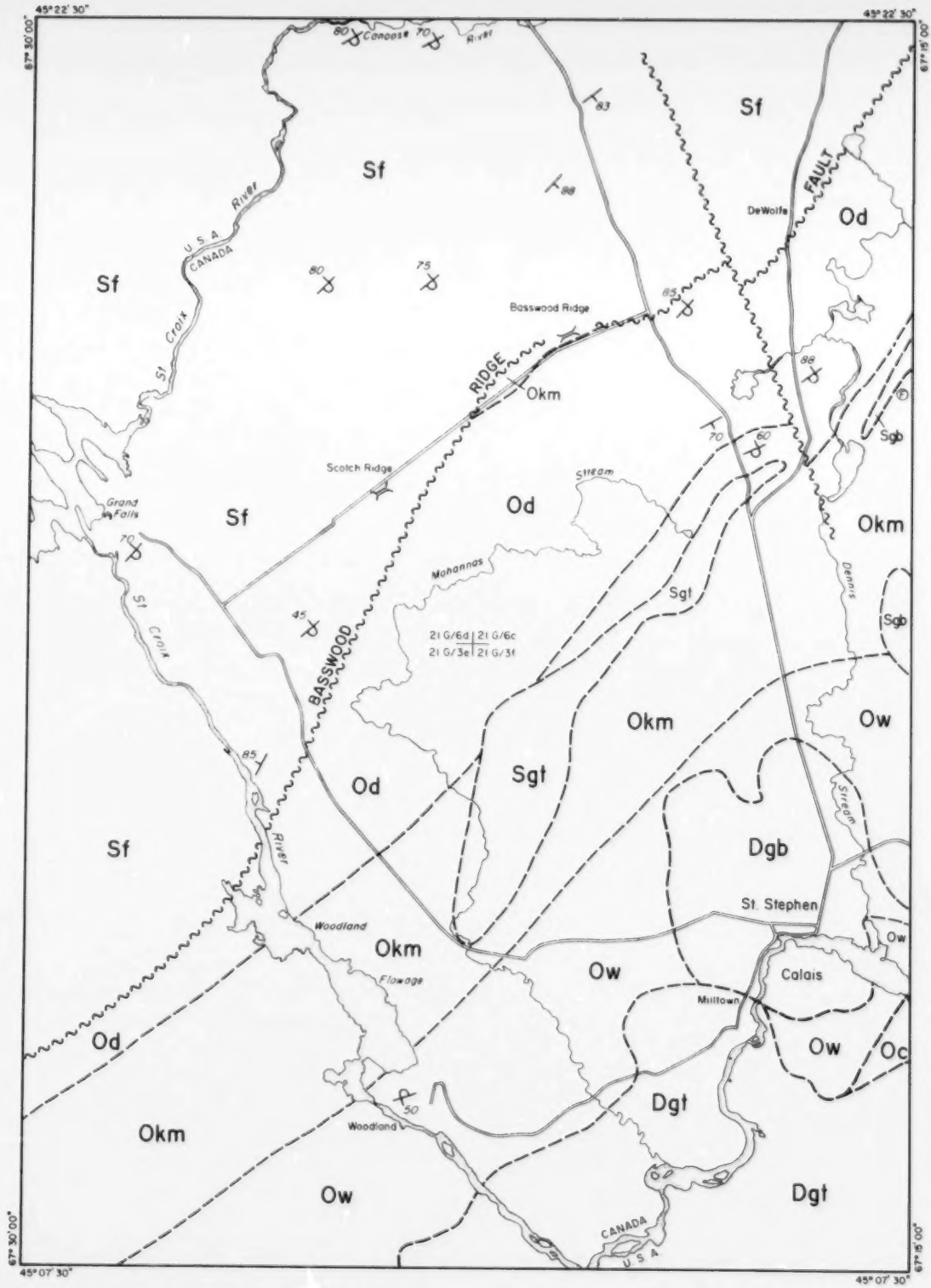


**FIGURE 4. Geology map of the western portion of the St. Croix Terrane.**

## LEGEND

**DEVONIAN**

White, subporphyritic biotite granite; light pink, equigranular biotite granite **(Dgt)**

**St. Stephen Complex (Dgb):** Peridotite, anorthositic gabbro, troctolite, norite, and gabbro

**SILURIAN**

**Mohannas Stock (Sgt):** Light grey, cataclastic biotite granodiorite containing augen of plagioclase

Dark green, foliated gabbro **(Sgb)**

**Flume Ridge Formation (Sf):** Light grey, thin- to medium-bedded micaceous, calcareous wacke and siltstone interstratified with light green to medium grey slate

**ORDOVICIAN**

**COOKSON GROUP**

**Kendall Mountain Formation (Okm):** Light grey, medium- to thick-bedded quartz arenite interstratified with black carbonaceous slate; minor granule and pebble conglomerate

**Digdeguash Formation (Od):** Dark and light grey laminated slate interstratified with thin- to medium-bedded, grey quartzofeldspathic wacke locally containing calc-silicate nodules

**Woodland Formation (Ow):** Thin- to medium-bedded, grey quartzofeldspathic wacke interstratified with dark and light grey laminated slate; minor calc-silicate beds

**Calais Formation (Oc):** Black carbonaceous slate, minor siltstone and pillow basalt

stratified with minor thin-bedded siltstone. A pillowed basalt member, about 100 m thick, occurs near the top of the formation. The flows have been thermally metamorphosed to a plagioclase-actinolite-biotite-sphene-iron oxide assemblage during emplacement of nearby Devonian gabbroic plutons. The basalt is moderately evolved with trace-element abundances similar to some passive continental margin tholeiites (Fyffe et al. 1988). Black slates in the contact aureoles contain abundant cordierite and andalusite porphyroblasts.

A thick sandstone-rich sequence, conformably overlying the Calais Formation northwest of St. Stephen, has been divided into three formations. The Woodland Formation contains rhythmically interstratified, thin- to medium-bedded (2-20 cm), quartzofeldspathic wacke and laminated slate. The wacke is well graded and about as equally abundant as the slate. The overlying Kendall Mountain Formation is mainly medium- to thick-bedded (10 cm-2 m) quartz arenite with thin interbeds of black slate. These arenites tend to weather chalky white in contrast to the rusty appearance of the other formations. The Kendall Mountain Formation is estimated to be between 500 and 700 m thick and the Woodland, about 800 m thick (Ludman 1987).

The graptolite Clonograptus herrmanni from the Calais Formation is Early Ordovician (Tremadocian) in age (Cumming 1967). Graptolites recently recovered from the Kendall Mountain Formation at Moores Mills include "Diplograptus foliaceous (Murchison), Corynoides sp., and Climacograptus brevis-putillus of the Climacograptus wilsoni zone of the mid-Caradocian (J. Riva, written communication, 1989).

Since the quartz arenites of the Kendall Mountain Formation are now known to be mid-Ordovician rather than Cambrian, they must occur well above the Tremadocian black shales of the Calais Formation (Figure 4). Previous correlations with the Cambrian Saint John Group of the Avalon Terrane (Ludman 1987) and lower Tetagouche Group of the Miramichi Terrane (Rast and Stringer 1974; Fyffe et al. 1983) are largely invalidated. Only Tremadocian black shale appears to have been a widespread facies as it is present in the Avalon and Miramichi terranes as well as the St. Croix Terrane (Fyffe et al. 1988; Figure 5).

The unfossiliferous Digdeguash Formation, assigned to the Silurian by Ruitenberg (1967), is here included as part of the Ordovician Cookson Group. It is lithologically similar to the Woodland Formation but contains a higher proportion of slate. Primary sedimentary structures at the conformable contact exposed near Moores Mills indicate that the Digdeguash underlies the Kendall Mountain Formation. The Digdeguash and Woodland formations, thus, are interpreted as facies equivalents occurring on opposite limbs of a regional syncline (Figures 4 and 5). The contact between the Digdeguash and Kendall Mountain formations is apparently faulted in adjoining areas (Ruitenberg 1967; Ludman 1987).

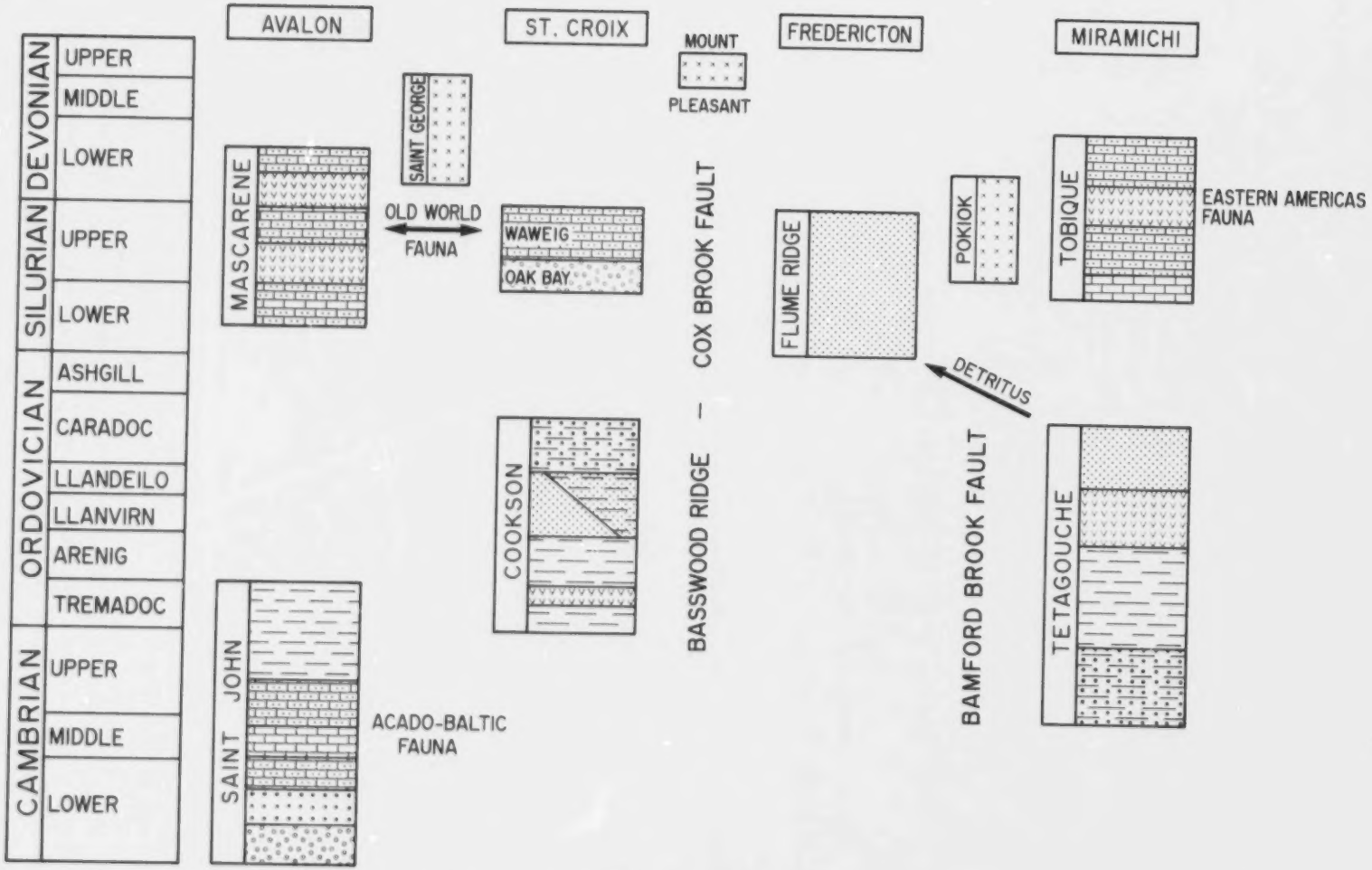


FIGURE 5. Stratigraphic, faunal, detrital and plutonic linkages across the Miramichi, St. Croix, and Avalon terranes. Legend: large open dots = conglomerate; dotted brickwork = sandstone; plain brickwork = limestone; large closed dots = quartzite; large closed dots and dashes = quartzite and slate; small dots = wacke; small dots and dashes = wacke and slate; chevrons = volcanic rocks; crosses = plutonic rocks.

The Flume Ridge Formation of the Fredericton Cover Sequence is an interbedded sequence of micaceous calcareous wacke, siltstone, and slate. Although the boundary between the Flume Ridge and Digdeguash formations has been regarded as gradational by previous workers, recent mapping proves it to be tectonic. The fault zone is exposed on Basswood Ridge, where it is injected by quartz veins, and on Cox Brook (to the east of the Moores Mills area), where it is intruded by Mount Pleasant-type granite porphyry. An overprinting set of asymmetric folds suggests that the Basswood Ridge-Cox Brook Fault is a southeastward-directed thrust (Figure 6). Thrusts of similar orientation are prominent features on seismic profiles across southern Maine (Unger et al. 1987). This thrusting event may account for the presence of thin slivers of complexly deformed Ordovician psammites and pelites within Silurian wackes along the trace of the Fredericton Fault (Fyffe 1988).

An unconformity with Late Silurian conglomerate of the Oak Bay Formation is exposed on Cookson Island on the southern margin of the St. Croix Terrane. The Oak Bay Formation is a shelf facies of interbedded polymictic conglomerates and sandstones. Quartz wacke pebbles in the conglomerate were obviously derived from the underlying Cookson Group, but the source of the volcanic and granitoid clasts is unknown, although they may possibly have been derived from the Silurian Mascarene Group or Precambrian rocks of the Avalon Terrane (Figure 3). The Oak Bay Formation, which is about 100 m thick, grades upward into a succession of grit, sandstone, and slate of the Waweig Formation (Cumming 1967; Ruitenberg 1967).

## TECTONIC SYNTHESIS

Tectonostratigraphic divisions of Newfoundland have been extended to the rest of the Appalachians by Williams and Hatcher (1982). On the southeastern margin of Iapetus, platformal Cambrian rocks containing an Acado-Baltic trilobite fauna define the Avalon Terrane, whereas a Cambrian quartz wacke succession characterizes the Miramichi (Gander) Terrane. The St. Croix Terrane of southwestern New Brunswick is situated between these terranes (Figure 3), but its tectonostratigraphic relationships to either are equivocal (Rast and Stringer 1974; E-an Zen 1983; Fyffe et al. 1983; Keppie 1985). Since the St. Croix Terrane contains a stratigraphy that has little in common with the Miramichi or Avalon terranes, it is best considered as a separate upper crustal segment (Fyffe and Fricker 1987).

Recognition of the Basswood Ridge-Cox Brook Fault has important implications for regional tectonic synthesis of the New Brunswick Appalachians. Silurian rocks of the Flume Ridge Formation, deposited within a basin to the northwest of the St. Croix Terrane, can no longer be considered to be laterally or vertically continuous with Silurian strata that were deposited unconformably on the Cookson Group in the Oak Bay

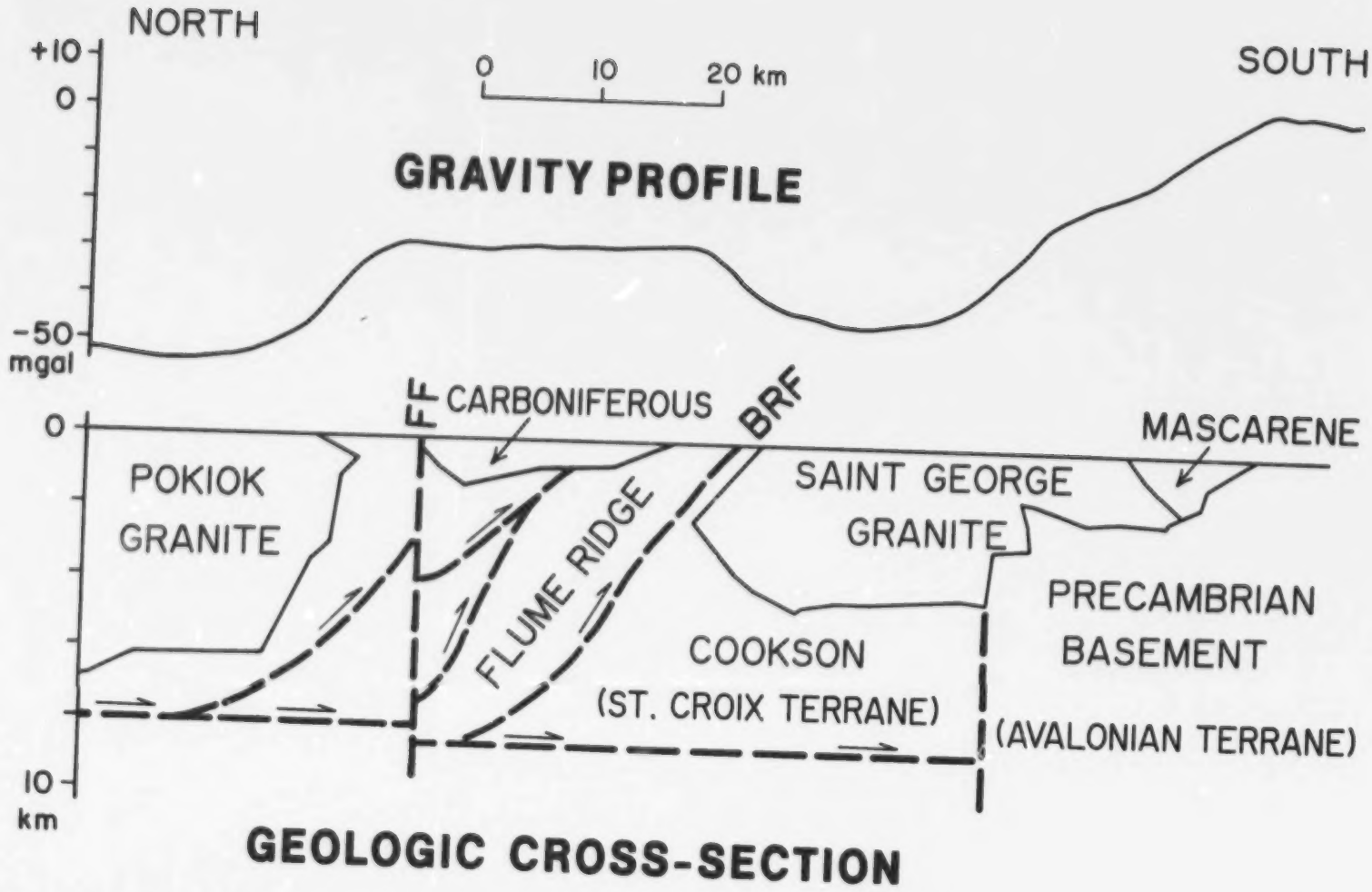


FIGURE 6. Schematic geological cross-section across terrane boundaries in southwestern New Brunswick based on mapping of Fyffe (1988) and this report, the gravity model of Thomas and Willis (1989), and seismic profile of Unger et al. (1987). FF = Fredericton Fault; BRF = Basswood Ridge-Cox Brook Fault.

area on the opposite margin of the St. Croix Terrane (cf., Ruitenberg 1967).

Siluro-Devonian volcanic and sedimentary rocks of the Mascarene Group, located in a belt extending along the southeastern boundary of the St. Croix Terrane, were presumably deposited unconformably on Precambrian rocks of the Avalon Terrane although contacts are now faulted (McLeod and Rast 1988; Currie 1988). This Early Silurian deposition within the Avalon Terrane apparently overlapped the St. Croix Terrane by the Late Silurian, since the Waweig Formation contains a Pridolian brachiopod assemblage identical to the Old World fauna of the Mascarene Group (Pickerill 1976). The Mascarene Group together with the Oak Bay and Waweig formations can, therefore, be considered as a Silurian cover sequence linking St. Croix and Avalon terranes.

Silurian rocks of the Fredericton Cover Sequence are linked by detritus to the Miramichi Terrane, which carries an Early Devonian Eastern Americas fauna on its northwestern margin (Fyffe and Fricker 1987). Although the Avalon and St. Croix terranes must have been contiguous in the Silurian, an upper crustal linkage between the Fredericton Cover Sequence (together with the Miramichi Terrane) and St. Croix Terrane cannot be demonstrated until the Late Devonian - the time of intrusion of porphyry dykes into the Basswood Ridge-Cox Brook fault zone (Figure 6). This suggests an independent origin for the Silurian rocks of the Fredericton and Mascarene cover sequences.

It is apparent that the region lying between Ordovician volcanic rocks of the Miramichi Terrane and Precambrian volcanic rocks of the Avalon Terrane acted as a zone of structural weakness throughout much of the Palaeozoic. This is reflected in a varied geological history across the zone represented by the unique Ordovician stratigraphy of the St. Croix Terrane, bimodal Siluro-Devonian volcanic rocks of the Mascarene Cover Sequence, and Silurian sedimentary rocks of the Fredericton Cover Sequence. The presence of a thinned continental crust beneath the St. Croix Terrane (Fyffe et al. 1988) may account for the structural complexity in the region.

The St. Croix terrane must have been juxtaposed against the Avalon Terrane sometime between the mid-Ordovician and Late Silurian as indicated by the depositional gap between the deformed Cookson Group and unconformably overlying Oak Bay conglomerate. During the latter stages of this deformational event, Silurian rocks of the Flume Ridge Formation were thrust over the Cookson Group from the northwest.

A steep fault identified beneath the Saint George Batholith by gravity modelling (Thomas and Willis 1989; Figure 6) may be a continuation of the Ketchum Brook Fault, which separates the Avalon and St. Croix terranes (McCutcheon and Ruitenberg 1987).

A number of similar northeast-trending faults have been recognized farther to the southeast within the Avalon Terrane. These include the Wheaton Brook, Belleisle, Kennebecasis, and Clover Hill faults, many of which show evidence of mid-Palaeozoic dextral displacement (Leger and Williams 1986). The Oak Bay conglomerate, which contains pebbles eroded from both the St. Croix and Mascarene terranes, was probably deposited in a local basin developed during this transcurrent movement.

## ECONOMIC GEOLOGY

Faults bounding the St. Croix Terrane have exerted considerable control on the emplacement of metal-bearing fluids. A seven inch-wide vuggy quartz vein on Basswood Ridge was worked in the 1930's, but it is not known if any gold was recovered. A shaft was put down in a quartz vein at Scotch Ridge, but again no information is available on whether gold was found (MacKenzie 1940). Tin-bearing greisen west of Kendron Brook and the tin-tungsten-molybdenum deposit at Mount Pleasant, both located to the northeast of the Moores Mills area, are situated along the trace of the Basswood Ridge-Cox Brook Fault. Several gold showings are associated with quartz veining along the Ketchum Brook Fault to the northeast of the Saint George Batholith (McLeod et al., this volume). Volcanic rocks are intercalated with black slates of the Cookson Group in the Ketchum Brook area and are host to possible stratiform copper deposits near Annidale (McCutcheon and Ruitenberg 1987).

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## GEOCHEMISTRY PROJECTS

Toon Pronk, Geochemist

Field projects in geochemistry include a stream-sediment and water survey (21 G/14), till mapping and sampling of 21 O/7 map area, and two methodology studies that were carried out jointly with the Geological Survey of Canada.

Consultation with federal and provincial geological survey branches and private industry has indicated that the objectives of our geochemical laboratory should shift more toward sample preparation, analytical control, and data handling rather than bulk analytical work.

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Les projets sur le terrain en géochimie comprennent une étude des sédiments de cours d'eau et d'eau (21 G/14), la cartographie de la moraine et l'échantillonnage de la zone cartographiée 21 O/7 ainsi que deux études méthodologiques menées conjointement avec la Commission géologique du Canada.

Des consultations avec les Directions des études géologiques du fédéral et du provincial ainsi qu'avec l'industrie privée ont montré que les objectifs de notre laboratoire de géochimie devraient plutôt être orientés vers la préparation d'échantillons, le contrôle analytique et le traitement des données que vers le travail analytique d'ordre général.

Till geochemistry data from the Riley Brook area (21 O/3), that was mapped/sampled in 1988, were released earlier this year (Pronk and Parkhill 1989). Data from previously mapped areas (21 O/9, 10, 15) is being compiled into a report of investigation that will deal with relations between pebble lithology and geochemistry of till units and the the glacial history of the area (Pronk et al. 1989).

Field efforts (Figure 7) have gone into surficial mapping/ sampling of map area 21 O/7 (Nepisiquit Lakes) (see Parkhill, this publication) and stream sediment and water sampling of 21 G/14 (Canterbury) at a density of 1 sample/2.8 $km^2$ with partial provincial and MDA funding. The Nepisiquit Lakes map area was also the subject of bedrock mapping in the Tobique-Chaleur belt (Wilson, this publication). A methodology study was initiated in the southeast quadrant of 21 O/10 (Upsalquitch Forks) by bulk sampling stream sediments and tills (joint effort with GSC, Peter Friske). This will be followed up next spring by detailed stream, till, soil, and biogeochemical sampling. Some 50 water sampling sites (4 samples at each site) were established throughout New Brunswick (21 G/8, 9, 10, 14, 21 H/5, 21 J/2, 7, 21 O/9, 21 P/12, 13) in different geological settings to evaluate the potential of water sampling in mineral exploration and environmental monitoring (in liaison with G.E.M. Hall and P.W.B. Friske, GSC). Unfiltered/ unacidified, filtered/ unacidified, filtered/acidified, and unfiltered/acidified samples were collected at each site to research settling and storage effects. New analytical

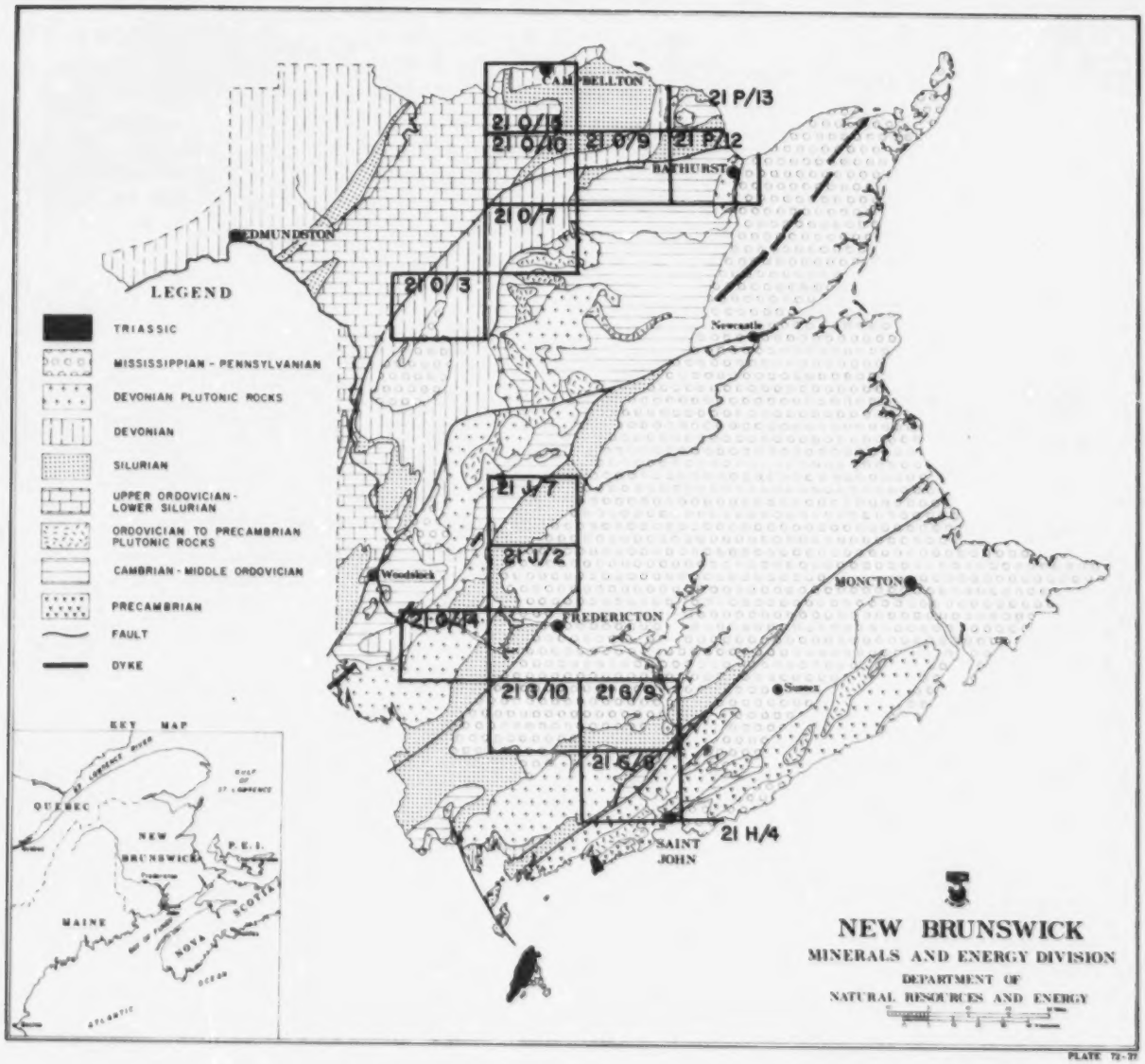


FIGURE 7. Geological map of New Brunswick showing the location of geochemical projects, 1989.

techniques [e.g., Inductively Coupled Plasma/Mass Spectrometry (ICP/MS)] make it possible to analyse for elements in ppb and ppt (parts per trillion!) instead of ppm and ppb. The easy, clear sample collection might make this the technique for geochemistry surveys in the future. Renewed sampling of the sites in the fall will indicate if there are also seasonal restraints on stream water sampling only.

The objectives and possible utilizations of the laboratory were evaluated (by C.F. Gleeson and Associates) before the

Geochemist position was filled. The new facilities were already in an advanced stage of construction. In order to establish new guidelines and/or objectives for the geochemistry section, visits were made to RPC (David Desjardins, John Stirling), the Nova Scotia Department of Mines, Geochemistry Section (Peter Rogers, Geochemist), the Technical University of Nova Scotia (Cyril Cole, Manager, Minerals and Engineering Sector), GSC, Exploration Geochemistry Subdivision (Peter Friske, Geochemist), Bondar Clegg laboratories (Russ Calow, Chemist), and Overburden Drilling Management, Ottawa (Stu Averill, President/Geologist). Further input was obtained through correspondence with P.H. Davenport (Newfoundland Department of Mines) and J. Fortescue (Ontario Geological Society). The overall results of this orientation exercise are the following: focus our efforts on sampling, sample preparation and analytical control using a system of control samples (field duplicates, blind duplicates and standard reference samples) that was developed by the GSC (Garrett, 1974) and that is presently being formatted to be handled on a PC (GSC, Exploration Geochemistry Subdivision). Some sample preparation equipment was purchased but has not yet been installed (some remodelling of our new quarters will have to take place). The hiring of a new technician (B. Edney recently retired) will enhance the new utilization of the geochemistry laboratory.

Presently, we utilize our geochemistry laboratory for the analyses of drill core to determine the potential of base-metal mineralization of the Carboniferous Basin. This project was started a few years ago and will be completed using the same techniques. From January to September, 520 drill-core samples and approximately 1000 till samples were analysed for Cu, Pb, Zn, Ag, Fe, Mn, Co, and Ni by Atomic Absorption and for Mo and W by colorimetric methods. The till samples were further analysed for Au, Ag, As, Sb, and Hg at a commercial laboratory. These till samples were obtained from several projects: Regolith mapping/till geochemistry - Riley Brook (MDA, Toon Pronk), Woodstock till sampling (Art Ruitenberg, Sussex Regional Office), Caledonia surficial mapping project (Allen Seaman, Marc Foisy), and some detailed studies (Murray Brook, Rocky Brook). Some of these data have yet to be released.

Future geochemical surveys will utilize commercial laboratories and multi-element packages for the analytical work, similar to GSC surveys that are considered standard throughout Canada. Sampling, sample preparation and analytical precision and continuity will be carried out/monitored by the Geochemistry Laboratory staff.

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# QUATERNARY STRATIGRAPHY YORK, SUNBURY, AND CHARLOTTE COUNTIES, NEW BRUNSWICK

A.A. Seaman, Quaternary Geologist

Fourteen separate ice-flow events that appear to be of regional extent have been identified in southwestern New Brunswick, plus several that may be of local extent only. The apparent chronological relationships between these events suggests that the ice-flow direction has varied gradually over time, within the range from east-northeastward clockwise through to westward. Up to eleven of these events have been observed, as striae, on a single bedrock outcrop. Till fabric measurements are equally complex, being polymodal, with up to nine peak fabric trends, all of which parallel striae trends from the region. Because of this complexity, neither the striae nor the till fabric trends can be used to predict the direction of till transport, critical for tracing a till geochemical anomaly back to its bedrock source. At this point in time, only the lithological composition of the till has this predictive ability.

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Quatorze événements glaciaires qui semblent être d'étendue régionale, ont été identifiés dans la région sud-ouest du Nouveau-Brunswick, en plus d'autres événements qui sont peut-être seulement d'étendue locale. Les rapports chronologiques entre ces événements glaciaires suggèrent que la direction de l'écoulement glaciaire a varié graduellement de temps en temps, de l'est-nord-est à l'ouest dans le sens des aiguilles d'une montre. Jusqu'à 11 de ces événements ont été observés, comme stries, sur la surface d'un seul affleurement rocheux. Les orientations des trames de till sont complexes aussi, parce qu'elles sont polymodales, avec jusqu'à neuf orientations. Chacune de ces orientations est comparable aux directions de l'écoulement glaciaire indiquées par les stries dans le secteur. A cause de cette complexité, ni les stries ni les orientations des trames de till ne peuvent servir à prédire la direction de transport du till, ce qui est critique pour faire remonter une anomalie géochimique à son origine dans le soubassement rocheux. En ce moment, seulement la composition lithologique du till peut servir à prédire la direction de transport du till.

## BACKGROUND

Rampton et al. (1984), based in part on the earlier work of Gadd (1973), identified five different ice-flow patterns in southwestern New Brunswick (NTS 1:250 000 scale map area 21 G). The first was an eastward-trending ice-flow event that was assigned a pre-Late Wisconsinan age. The remaining four flow patterns were assigned to the last glacial interval, the Late Wisconsinan. These were the southeast-trending Tay and south-trending Oromocto flow patterns in the eastern part of the area, and the southeast-trending St. Stephen flow pattern and a late eastward flow pattern, the Passamaquoddy diversion, in the western part of the area (Rampton et al. 1984, their Figure 27). Based on the study of the eastern Saint George Batholith area in the southeastern part of the study area, Thomas et al. (1987, p. 8) proposed the following relative chronology between the flow patterns: "early eastward flow (circa 110°) ...

followed by a south-southeastward flow (circa 165°) and finally by a southward flow (175°) ... evidence suggests that east-west flow (88°) occurred over a small area just prior to final deglaciation."

The observations of the past two years have revealed a significantly more complex situation. Firstly, the major ice-flow event in one area (i.e., the one recorded by the most abundant and heaviest striae), may decrease in magnitude to become a minor event in an adjacent area. As a consequence, the local flow patterns identified by Rampton et al. (1984) have now been found to be of regional extent. Secondly, there are many more ice-flow events than previously recognized.

**PRELIMINARY CHRONOLOGY OF GLACIAL EVENTS**

To date, more than 250 glacially striated outcrops have been examined in southwestern New Brunswick (Figure 8). Most of these were multiply striated, exhibiting two to eleven separate sets of striae (i.e., each set is presumed to relate to one ice-flow event; as in a set indicating ice flow toward 138° to 144°, with a mean flow trend of 142°, being distinct from a set indicating ice flow toward 148° to 153°, with a mean flow trend of 150°). Preliminary analysis of the measured striae trends suggests that there are 16 peak directions (sets) in the ice-flow direction data set for southwestern New Brunswick (Table 1). Of these peaks, 14 recur with considerable regularity (i.e., in at least half of the 1:50 000 scale map areas in the area), and are interpreted to relate to flow events of regional extent. The remaining two peaks, trending approximately east-northeastward, also appear to be of regional extent. In addition, several individual sites have been discovered that record ice flow in a westerly direction (toward 240° through to 288°), probably relating to late, local flow events. To add to the complexity, it appears that some of the peaks may correspond to more than one flow event (i.e., a given direction of flow may have occurred more than once).

The dominant ice-flow directions in the region are southeastward to south-southeastward (toward 142°, 150°, and 160°), both in terms of the number of outcrop surfaces bearing striae of these trends, and in the effect that these flow events had in shaping and streamlining the bedrock surfaces. In most cases, the other striae directions occur on surfaces shaped by these flow directions, without significantly changing the shape of the surface, suggesting firstly that these southeast-trending flows were the earliest, and secondly, either that these other events were of less strength (i.e., thinner or slower moving ice), or that the bedrock surface was protected from significant erosion (by an earlier deposited till sheet). Ninety-five definite cross-cutting relationships observed between pairs of striae sets support this interpretation. Initial ice-flow appears to have been toward the south-southeast, followed by flow toward the southeast. The ice-flow direction then appears

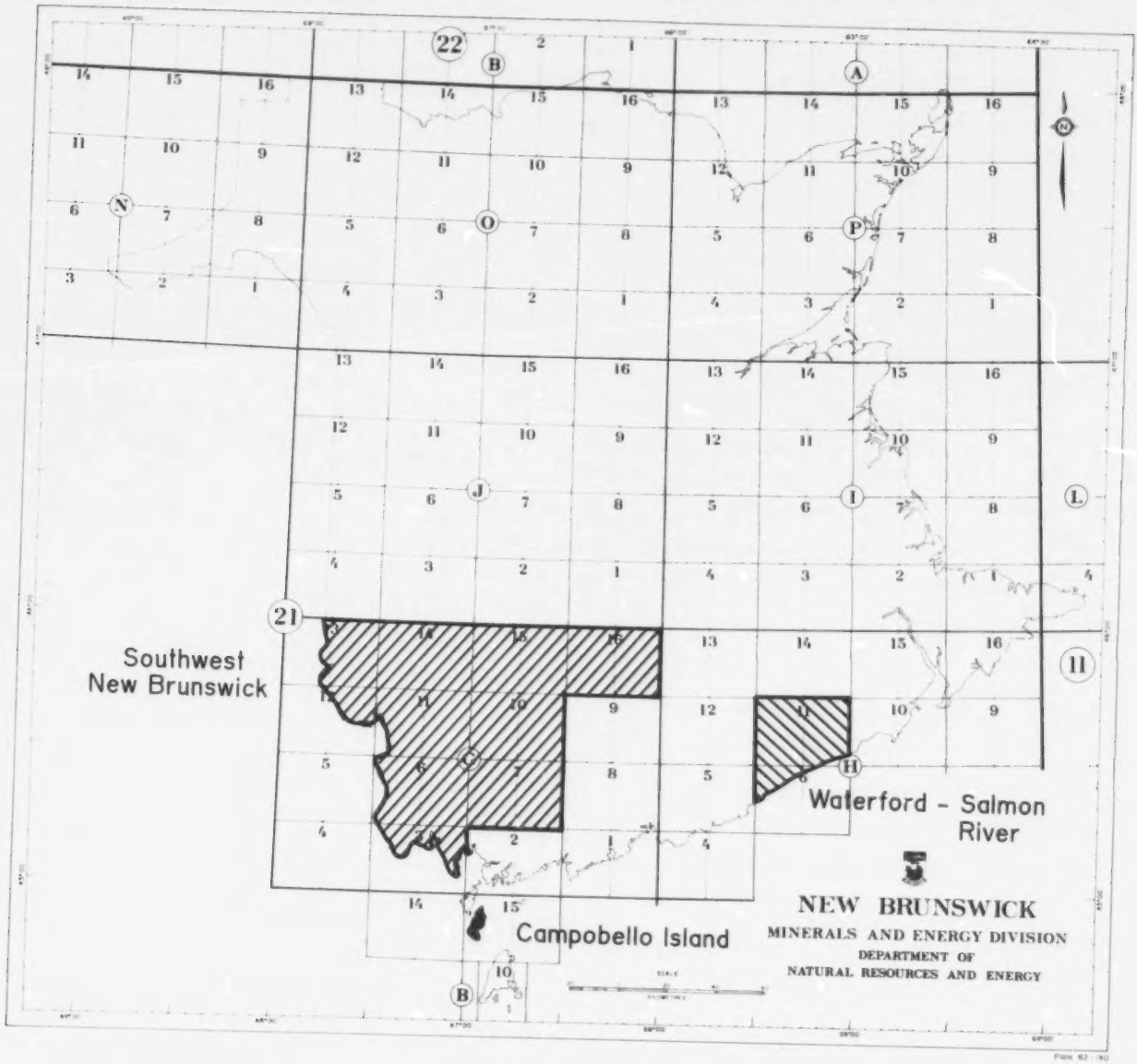



FIGURE 8. Index map: Quaternary stratigraphy of southern New Brunswick, 1989.

to have rotated clockwise toward the south and then the southwest, followed by a rotation counter-clockwise back toward the southeast and then the east and the east-northeast (Figure 9). However, there is some evidence to suggest that there may have been earlier southward flows that preceded the southeastward flows. If this interpretation is correct, it is possible that some flow directions (e.g., 150°) may have occurred two or three times. As noted above, there is also some evidence of local flow events that trended generally westward. These

TABLE 1. DISTRIBUTION OF PEAK ICE-FLOW DIRECTIONS, BY NTS MAP AREA

| Trend | G/01 | G/02 | G/03 | G/06 | G/07 | G/08 | G/09 | G/10 | G/11 | G/12 | G/13 | G/14 | G/15 | G/16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 064° | | | | | X | | | O | O | | | O | X | |
| 075° | X | 0 | X | 0 | | X | | | 0 | | | | | |
| 095° | | X | | 0 | | X | | 0 | 0 | | | | X | |
| 102° | X | 0 | | 0 | 0 | X | | 0 | 0 | | | | 0 | O |
| 110° | X | 0 | X | O | 0 | X | | O | 0 | | | 0 | 0 | |
| 123° | X | X | 0 | 0 | X | | X | 0 | 0 | X | 0 | O | 0 | |
| 130° | X | 0 | 0 | 0 | 0 | X | X | O | 0 | 0 | 0 | 0 | 0 | O |
| 142° | X | X | 0 | 0 | 0 | X | X | O | 0 | 0 | 0 | 0 | 0 | X |
| 150° | X | X | 0 | 0 | 0 | X | X | 0 | 0 | X | 0 | 0 | 0 | X |
| 160° | 0 | 0 | X | 0 | 0 | X | X | 0 | 0 | | 0 | 0 | 0 | X |
| 171° | 0 | 0 | X | O | 0 | X | X | 0 | 0 | | O | 0 | 0 | 0 |
| 180° | X | X | | O | 0 | X | X | 0 | 0 | | O | 0 | 0 | 0 |
| 190° | 0 | 0 | X | | 0 | X | X | O | O | | O | O | O | 0 |
| 201° | 0 | X | | 0 | O | X | | O | O | | | O | 0 | 0 |
| 213° | O | | | | 0 | X | X | O | O | | O | O | O | X |
| 225° | | | | O | O | X | | O | O | | | O | O | |

O = observed in the map area

0 = both observed, and reported in the literature for the map area

X = reported in the literature for the map area

appear to be late events, but their chronological relationships to the late eastward-trending events is unknown. [No evidence has yet been observed of the early eastward flow event reported by Rampton et al. (1984) and Thomas et al. (1987)].

Given the broad range that the glacial striae cover, and the number of directions that can occur on a single rock outcrop, it is apparent that they cannot serve as accurate indicators of glacial transport direction. For this purpose it is necessary to look at the glacial materials themselves.

## TILL STUDIES

Till fabrics were measured at 18 sites within the study area, in fresh till exposures 0.2 to 0.3 m thick lying at least 0.2 m below the base of the soil B-horizon. It was hoped that the dominant trend of the elongated clasts in the till would indicate the direction of till transport. Unfortunately, this has not proven to be the case. While the statistically preferred fabric for each site (calculated using the eigenvector method) is both strong (non-random at the 99% confidence level) and closely parallel to one of the peak striae trends, the fabrics vary widely between sites. Of the 16 peak striae trends listed in Table 1, ten have appeared as the principal eigenvector in the till fabric analyses, with no one direction occurring at more than three sites. In many cases the till fabrics differ significantly in trend from the striae on the underlying or adjacent bedrock surfaces.

Plotting of the till fabrics by hand (as in Figure 10) has revealed the probable reason for the wide variation in till fabric directions. Each fabric is polymodal, with between three and nine peaks, each of which closely parallels one of the peak striae trends (with the exception of a peak at about 085°, that occurs in several of the fabrics, suggesting an additional ice-flow event that is not readily evident in the striae data). The statistical till fabric trends are thus averages of several populations of data. The reasons for the presence of multiple populations at each site is unknown, and warrants further investigation.

## IMPLICATIONS WITH RESPECT TO DRIFT PROSPECTING

The variability in striae and till fabric directions in southwestern New Brunswick renders them of little use in mineral exploration. For example, if a significant geochemical anomaly occurred in the till at Site 88-16a (Figure 10), it would be impossible to determine, using the striae and till fabric data, the appropriate up-ice direction in which to search for the bedrock source of the anomaly. The striae on the immediately adjacent bedrock surface trend toward 164° (ranging from 158° to 168°), 183° (ranging from 178° to 186°), and 201° (ranging from 199° to 204°). The statistical till fabric trends toward 060°, while in detail the fabric has eight peaks, including

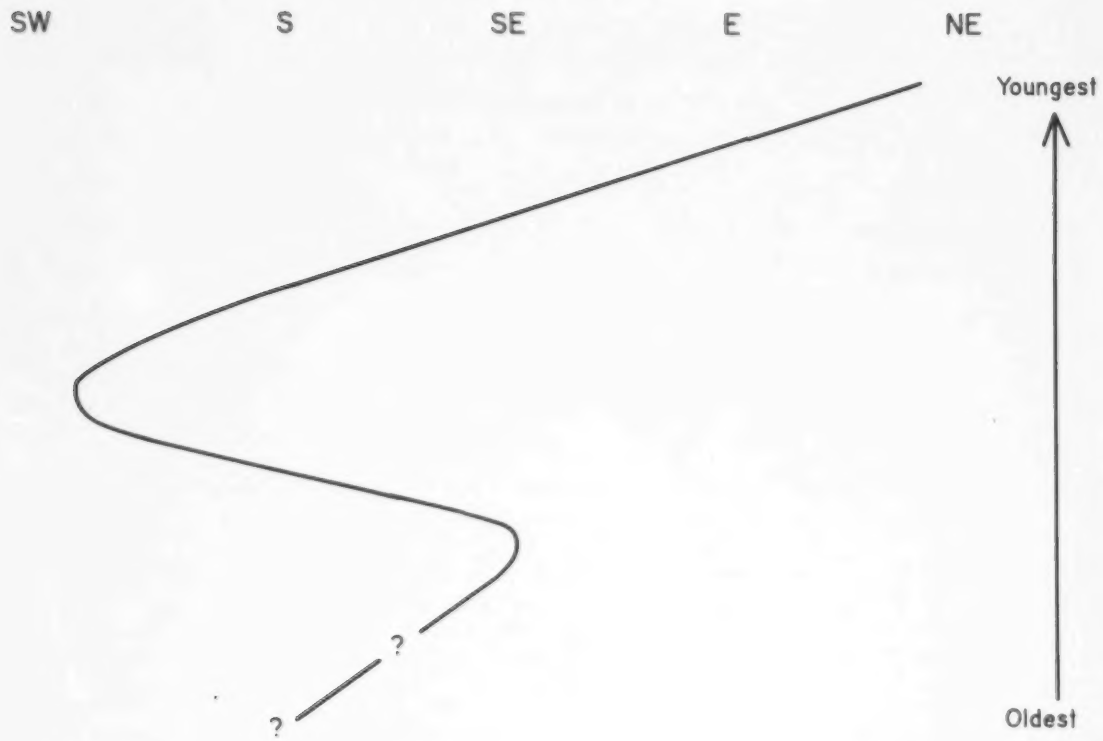


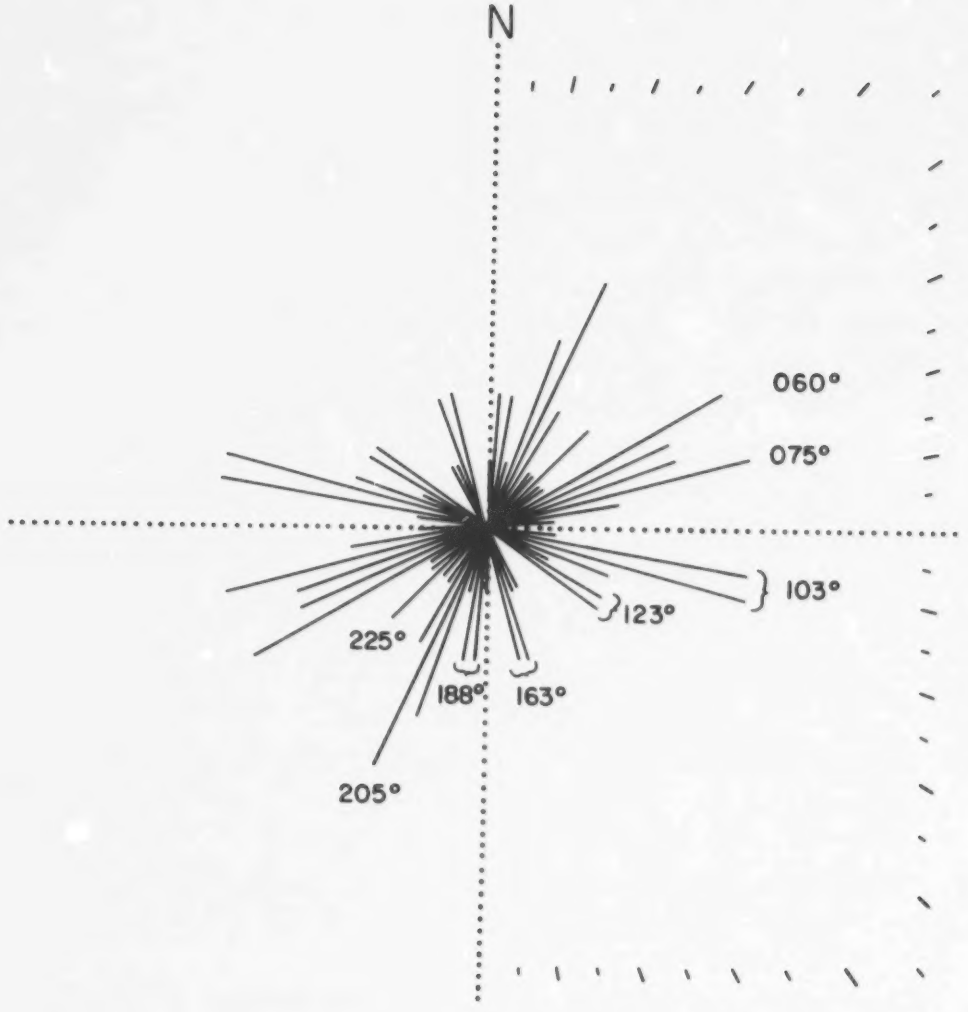

FIGURE 9. Schematic representation of the apparent chronological variation in ice-flow direction in southwestern New Brunswick.

three that parallel the striae trends. The actual till transport direction could be any of these directions, or, more likely, a dogleg-like combination of any or all of them.

Consequently, at this point in time, only the lithologic character of a till has the potential to serve as a definitive indicator of its source area. The geochemical signature of the till may also prove to be of value in indicating its source area, if the geochemical signature of the bedrock sources is known. Further studies, concentrating on the lithologic and geochemical characteristics of the tills of southwestern New Brunswick, are in progress.

Figure z
TILL FABRIC

Site : 88-16a
N.T.S. : 21 G/10
U.T.M. : 728 542




n=30

Notes: -principal eigenvector trends toward 060°
-adjacent bedrock surface is striated at 164°, 183°, and 201°

FIGURE 10. Mirror-image till fabric plot.

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# QUATERNARY GEOLOGY OF THE WATERFORD AND SALMON RIVER MAP AREAS; KINGS, SAINT JOHN, AND ALBERT COUNTIES, NEW BRUNSWICK

M. Foisy and A.A. Seaman

Field studies this year have confirmed that the Central Plateau area of the Caledonian Highlands was not a nunatak area during the Late Wisconsinan. The soil thicknesses developed on the tills in the area are comparable to those developed on Late Wisconsinan tills elsewhere in New Brunswick. In addition, the tills have been found, in considerable thickness, underlying the colluvial deposits within the river valleys. Palaeocurrent measurements in glaciofluvial deposits near the northern margin of the Highlands indicate that these deposits were formed by northward-flowing meltwater, suggesting that a remnant ice-cap remained over the area following regional deglaciation. Some evidence for northward-flowing ice has also been discovered. However, in general, the glacial events in this area seem to be similar to the regional events in southwestern New Brunswick.

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Cette année, des travaux dans la région du plateau central des hautes-terres du Calédonien ont confirmé que cette région n'a pas été une région de nunatak pendant le Wisconsinien supérieur. Les épaisseurs des sols sur les tills de la région sont comparable à celles sur les tills d'âge Wisconsinien supérieur dans les autres parties du Nouveau-Brunswick. Aussi, il y a des tills, quelque fois très épais, sous des dépôts de colluvions dans les vallées des rivières. La direction de l'écoulement des dépôts fluvio-glaciaires près du bord des hautes-terres indique que ces dépôts ont été faits par de l'eau de fonte qui s'est écoulée vers le nord. Ceci suggère qu'il y a eu une calotte de glace qui est restée sur les hautes-terres après la deglaciation régionale. Des données indiquent qu'il y a eu aussi un écoulement glaciaire vers le nord. En général, les évenements glaciaires sont semblables aux évenements régionaux dans le sud-ouest du Nouveau-Brunswick.

As in southwestern New Brunswick, the dominant ice-flow directions in the Waterford (21 H/11) and Salmon River (21 H/6) map areas, as recorded by striae, trend southeastward to south-southeastward (Figure 8). Similarly, the known ice flow directions cover a very broad range, and appear to have shifted gradually over time. Due to the nature of the bedrock in this area, definitive cross-cutting relationships are very rare. However, the limited data available suggests that the chronological sequence is similar in pattern to that for southwestern New Brunswick. Further work in intervening areas will be required to determine whether there is any actual correlation between the two areas.

A significant discovery of this year is evidence, at two sites, for glaciation by ice flowing northward out of the Bay of Fundy. Both sites lie within a few kilometres of the coast, indicating ice advances out of the Bay of Fundy, probably from Nova Scotia. At one site, a knob-and-tail feature trending north-northwestward appears to record an early ice-flow event, possibly the event responsible for the pre-Late Wisconsinan northward transport of Precambrian boulders from the Central

Plateau area postulated by Rampton et al. (1984). At the second site, wedge striae define what appears to have been a late, northwest trending event.

Till mapping, plus reconnaissance sampling at 81 sites (one sample/16 $km^2$), has revealed that the till cover is much more extensive, and locally much thicker, than interpreted by Rampton and Paradis (1981) and Rampton et al. (1984). The surface till over the Precambrian rocks of the Caledonian Highlands is typically a compact, grey silty-sandy to sandy-gravelly till, with the texture being dependent on the lithology of the source bedrock. The finest tills are typically derived from metavolcanic rocks, while those derived from granite are typically stony and bouldery. Tills developed from the sedimentary rock units surrounding the Precambrian core of the Highlands are typically red and silty. The till thickness varies from a few tens of centimetres to in excess of 50 m in some of the deep valleys near the coast. In the Point Wolfe River and the Pollet River valleys, a grey surface till has been observed to overlie red till. The significance of this stratigraphic sequence has yet to be determined. At several sites, the surface till has been observed to overlie shattered bedrock, which appears to be a deformation till.

The volume of colluvium in the valleys in the area was greatly overestimated by Rampton and Paradis (1981) and Rampton et al. (1984). In most cases the colluvium has been found to blanket till, even along the steep sides of V-shaped valleys. This indicates that the valleys were carved prior to glaciation, filled with till, and are now being re-excavated, rather than being freshly carved subsequent to the last glaciation of the area, as was previously proposed. In addition, the soil development on the tills is poor throughout the area, typically 0.4 to 0.6 m in thickness, as elsewhere in New Brunswick, confirming that the area was not a nunatak zone during the Late Wisconsinan.

Northward-trending palaeocurrents have been measured in the kame complex deposits along the northern margin of the Caledonian Highlands (at the northern border of the Waterford map area), and also in an esker ridge in the northern part of the Pollet River valley. These observations, plus the northeastward palaeocurrent trend in the delta at Elgin, to the north (Brinsmead and Seaman 1987), suggest that deglaciation of the Highlands occurred later than the surrounding area, probably due to the presence of a local ice cap, as previously suggested by Brinsmead and Seaman (1987), Foisy (1989), Foisy and Prichonnet (1988), and Seaman (1988).

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GEOLOGICAL SURVEYS BRANCH

MINERAL DEPOSITS AND GIS SECTION

## ACTIVITIES OF THE MINERAL DEPOSITS AND GIS SECTION

R.R. Irrinki, Senior Geologist

The Geological Surveys Branch created this separate section in order to give a higher profile to the Mineral Deposits and Geographic Information Systems activities. The section is staffed by R.R. Irrinki (Senior Geologist), W.W. Gardiner (Mineral Deposits Geologist), and G.W. Crouse (Core Manager and MESP Coordinator).

L.W. McNeill, loaned from Information Systems Branch of DNRE, is working as the operator of the Geographic Information Systems (GIS). P. Rennick, project geologist, was hired to computerize drill-hole data and carry out geological mapping of the Murray Brook Deposit and surrounding area.

R.R. Irrinki continued the computerization of drill-hole data on major metallic mineral deposits in New Brunswick. The drill-hole information on Lake George, Turgeon, and Murray Brook deposits (Figure 11) has been entered into the database.

Several cross-sections, longitudinal sections, and plans outline favourable targets for antimony and gold exploration at the Lake George Deposit. These results have been discussed with Mr. Charles Morrissey of Dominion Explorers Inc.

An internal study was conducted on the Turgeon Deposit. Several cross-sections, longitudinal sections, and plans were plotted based on drill-hole data. Probable in situ reserves were then estimated.

A comprehensive study on the Murray Brook Deposit was carried out by P. Rennick.

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La Direction des études géologiques a créé cette section distincte afin de donner une importance accrue aux activités reliées aux gisements de minéraux et au système d'information géoscientifique. Le personnel de cette section se compose de: R.R. Irrinki, géologue confirmé, W.W. Gardiner, géologue des gisements de minéraux, et G.W. Crouse, directeur des forages et coordonnateur du PSEM. L.W. McNeill, prêté par la Direction des systèmes d'information du MRNE remplit les fonctions d'opérateur du système d'information géoscientifique (SIG). P. Rennick, géologue des projets, a été engagé pour informatiser les données des forages et effectuer le relevé cartographique géologique du gisement de Murray Brook et de la région environnante.

R.R. Irrinki a poursuivi 1'informatisation des données des forages reliés aux principaux gisements de minéraux métalliques

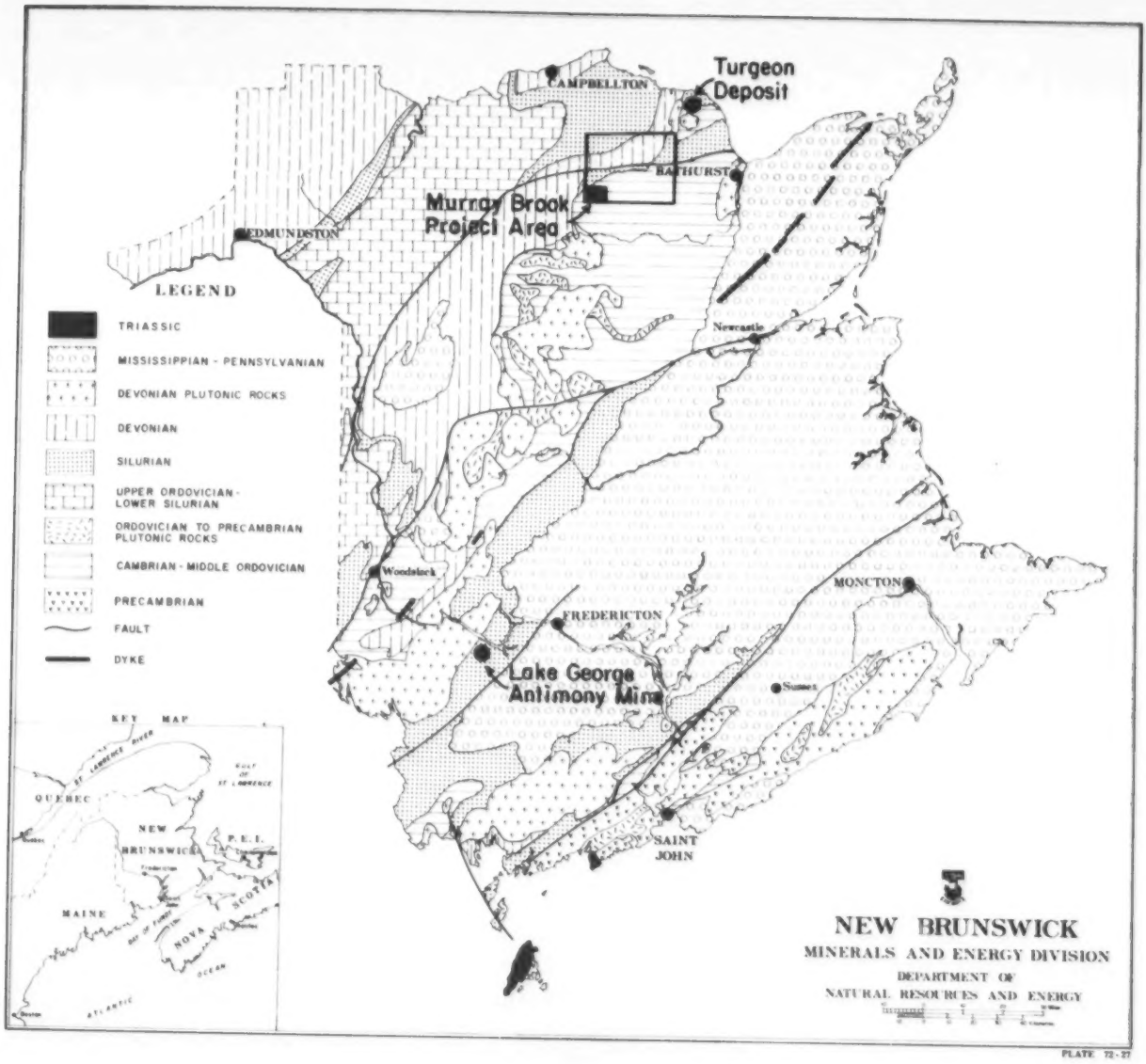


FIGURE 11. Location map for Turgeon, Murray Brook, and Lake George projects.

du Nouveau-Brunswick. Les renseignements sur les forages dans les gisements de Lake George, Turgeon, et Murray Brook (illustration 11) ont été entrés dans la base de données.

Plusieurs sections transversales, longitudinales ainsi que les plans permettent d'espérer des résulats encourageants pour la prospection d'antimoine et d'or au gisement de Lake George. Ces résultats ont été examinés et approuvés par M. Charles Morrissy de Dominion Explorers Inc.

Une étude interne a été menée sur le site du gisement Turgeon. Plusieurs sections transversales, longitudinales ainsi que des plans ont été tracés en se basant sur les données des forages. Nous avons ensuite procédé à l'estimation des réserves du site.

Une étude poussée du gisement de Murray Brook a été effectuée par P. Rennick.

## GEOGRAPHIC INFORMATION SYSTEM (GIS) PILOT PROJECT

R.R. Irrinki, Senior Geologist

The purpose of the project is to evaluate the potential of GIS (Geographic Information Systems) techniques (using the locally developed CARIS software), especially to superimpose data from various maps showing geoscientific information. The techniques that are being tested must also allow the retrieval of cartographic and descriptive data as determined by the search criteria defined by the user. The project will then evaluate the use of CARIS as a resource management tool for the Minerals and Energy Division.

The area chosen for the pilot project is NTS map sheet 21 O/8 (one of 90 such sheets in N.B.) because of the availability of LRIS standard digitized base maps and preplotted assessment data. This map sheet contains twenty-five 1:10 000 base maps. Assessment data related to geology, geophysics, and geochemistry were plotted on one hundred and eighty 1:10 000 scale hard-copy maps.

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Le but du projet est l'évaluation de l'utilité possible des techniques des SRG (systèmes d'Information Géographique) en utilisant les techniques CARIS de source locale, surtout pour la superposition les données de cartes à données géoscientifiques. Les techniques à l'essai doivent permettre la récuperation des données cartographiques et descriptives en suivant les critères de recherche etablies par l'utilisateur. Le project évaluera alors l'utilisation de CARIS comme outil de gérance pour la Service des Minéraux et d'Energie.

La région choisie pour le projet pilote est la feuille 21 O/8 du STN (une de 90 feuilles semblables au N.B.) à cause de la disponibilité des cartes de base du RTSI (régistre de terrain en système informatisé) et données d'évaluation minière déja sur cartes. Cette feuille renferme vingt feuilles de carte de base à 1:10 000. Les travaux statutaires en géologie, géophysique et géochimie sont mise en carte sur cent et quatre-vingts feuilles à l'echelle de 1:10 000.

## GEOSCIENCE INFORMATION SYSTEM

### INTRODUCTION

The Geological Surveys Branch approved a pilot project to establish the Geoscience Information System (GIS). After six months of negotiations, on June 29, 1989, the Geological Surveys Branch of the New Brunswick Department of Natural Resources and Energy accepted financial assistance ($225 000) offered by the Department of Commerce and Technology. The offer is under the Industrial Innovation and Technology Development Subsidiary Agreement and is for the purchase of GIS hardware and the cost of consulting to customize the CARIS (Computer Aided Resource Information System) software to the Geoscience Information System (GIS).

Configuration of the hardware consists of one UNISYS 5000 minicomputer, one SUN 4 workstation, one 48" X 36" size pen plotter, and one 48" X 36" size digitizing table. INGRES

embedded version and CARIS will be used as GIS software.

The main purpose of the project will be to evaluate the potential of GIS techniques, especially for superimposing data from various maps showing geoscientific information. The area chosen for the pilot project is NTS map sheet 21 O/8, which can be divided into twenty-five 1:10 000 map sheets (Figure 12).

## PRODUCTION SCHEDULE

Sixteen steps are planned for the orderly completion of the pilot project. Although the 12 month schedule (Table 2) will begin after the proper installation of hardware and software, some of the steps are already in progress.

### CREATION OF GEOGRAPHIC BASE MAPS (Steps 1, 2, and 3)

Geological Surveys Branch geologists obtain base maps from several sources: 1) Energy, Mines and Resources, Ottawa for 1:50 000 and 1:250 000 UTM maps; 2) New Brunswick Department of Natural Resources and Energy for 1:10 000 and 1:15 840 scale base maps; 3) LRIS and MRMS for 1:10 000 scale base maps.

### CREATION OF 1:10 000 DIGITAL BASE MAPS (Step 1)

MRMS digitized 1:10 000 base maps for the 21 O/8 map sheet (project area) by using GEOBASE. These digitized files will be converted to the CARIS format. Hard copies will then be produced and compared with the existing 1:10 000 base maps. As the geocompilation data has been plotted on these base maps as several overlays, it is essential to have identical base maps for digitization of the data.

### CREATION OF 1:20 000, 1:50 000, and 1:250 000 DIGITAL BASE MAPS (Step 2)

The 1:10 000 digital bases produced above will be used to create 1:20 000-, 1:50 000-, and 1:250 000-scale base maps. Hard copies produced from these digital bases will be compared against the existing 1:50 000 and 1:250 000 maps. Necessary corrections will then be made to suit the needs of the Mines Division.

### CREATION OF 1:250 000 BASE MAPS USING SCANNED DATA (Step 3)

The 1:250 000 scanned base maps are available from Energy, Mines and Resources, Ottawa. The rasterized 21 O map sheet will be vectorized in order to use the CARIS software. A hard copy will then be produced and compared to the existing map.

### DESIGN OF GRAPHICAL MENU (Step 4)

A graphical menu will be designed to digitize geological, geophysical, and geochemical maps. In order to digitize large

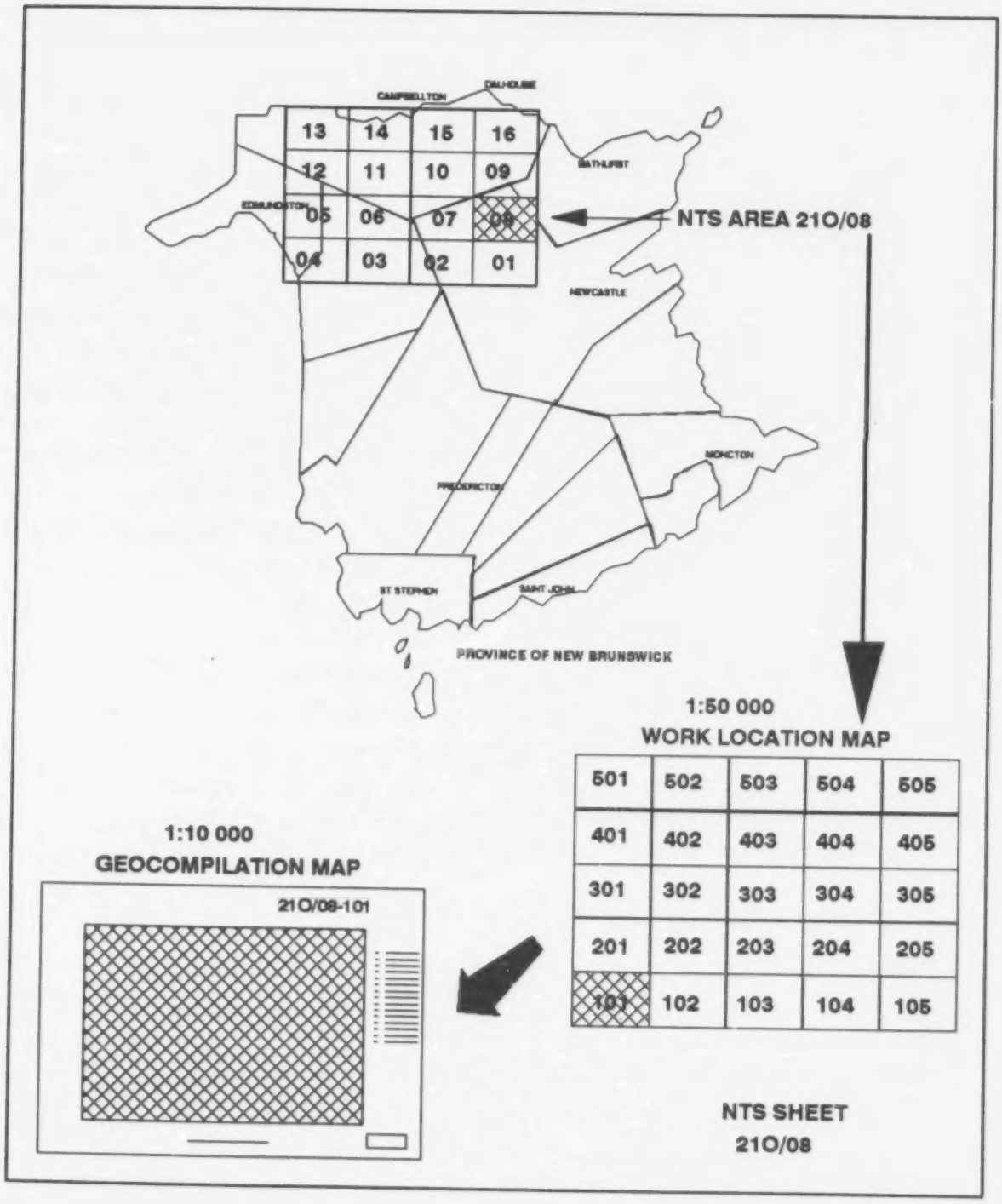


FIGURE 12. Index map showing part of the NTS grid for northern New Brunswick (21 O) and the location of NTS 21 O/8. The inset shows the numbering system for the twenty-five 1:10 000-scale geocompilation maps within 21 O/8.

TABLE 2. TWELVE-MONTH SCHEDULE OF GIS PILOT PROJECT

| WORK SCHEDULE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transfer of digital 1:10 000 (MRMS) base maps to CARIS format | X | | | | | | | | | | | |
| Creation of 1:20 000, 1:50 000, and 1:250 000 base maps (both digital and hard copies) from the above 1:10 000 base maps | X | X | | | | | | | | | | |
| Transfer of scanned 1:250 000 base map to CARIS format | | X | | | | | | | | | | |
| Design of graphical menu to digitize geoscience compilation maps | | X | X | X | X | | | | | | | |
| Manual digitization of geology maps (1:10 000, 1:15 840, 1:50 000, and 1:250 000); scanning of maps(?) | | | | X | X | X | X | X | X | X | | |
| Conversion of mineral occurrence file (dBase) to INGRIS | | | | X | X | X | X | X | X | | | |
| Conversion of geochemistry files to INGRIS | | | | X | X | X | X | X | X | | | |
| Conversion of mineral deposit data to INGRIS | | | | | | X | X | X | X | | | |
| Create an interface to integrate GSC geophysical data to CARIS | | | | | | X | X | X | X | | | |
| Digitize claim map (1:50 000) and integrate claim tracking system (dBase) to CARIS (INGRIS) | | | | | | X | X | X | X | | | |
| Digitize mining leases, reclamation | | | | | | | | X | X | | | |
| Digitize surficial geology, industrial minerals, and gravel pits, etc. | | | | | | | | | X | | | |
| Integration of spatially referenced data | | | | | | | | X | X | X | | |
| Spatial analysis and modelling | | | | | | | X | X | X | X | X | |
| Demonstration and presentation | | | | | | | | | X | X | X | X |
| Documentation | | | | | | | | | | X | X | X |

amounts of geoscience compilation maps, development of specialized graphic digitization interface menus for each type of map is critical.

**MANUAL DIGITIZATION OF GEOSCIENCE MAPS (Step 5)**

Geoscience data containing lithology, structural geology, mineralization, mineral deposits, drill holes, geophysical, and geochemical anomalies are compiled from the assessment files and are plotted on 1:10 000 maps. There are 180 such maps in the 21 O/8 NTS map sheet and are available only as hard copies.

Besides the geoscience compilation maps, geological maps are available on 1:15 840, 1:50 000, and 1:250 000 scale.

Although manual digitization is planned for most of these maps, we will explore the possibility of scanning a few maps.

**CONVERSION OF MINERAL OCCURRENCE DATABASE (Step 6)**

The data on 800 mineral occurrences have been maintained by "New Brunswick Computerized Mineral Occurrence Database", which is managed by several dBase files.

Mineral occurrences within the 21 O/8 NTS map sheet will be retrieved from the Mineral Occurrence Database. A conversion program will be made to transfer dBase files to the alpha-numeric database of the system (INGRES).

**CONVERSION OF GEOCHEMISTRY FILES (Step 7)**

Most of the geochemical data are plotted on 1:50 000 geographic bases. Some of the data are also stored as a computer file on an IBM mainframe computer. A conversion program will be developed to transfer geochemistry files to the alphanumeric database of the system (INGRES).

**CONVERSION OF MINERAL DEPOSIT DATABASE (Step 8)**

Data on several mineral deposits are managed by dBase files. A special software package by GEOSTAT SYSTEMS INTERNATIONAL INC. has been used to manipulate these data. A conversion program will be made to transfer the mineral deposit database files to the alphanumeric database of the system (INGRES).

**INTEGRATION OF GEOPHYSICAL DATA (Step 9)**

Both hard copies and digital tapes of airborne geophysical data, such as magnetic, VLF, and gravity are available from Energy, Mines and Resources, Ottawa. An interface will be developed to integrate EMR geophysical data to the system.

**CLAIM TRACKING SYSTEM (Step 10)**

The Mineral Development Branch of the Mines Division keeps track of the claims staked in the Province by using a Claim Tracking System, that is managed by dBase programs. Claims are manually plotted on 1:50 000 scale maps and are frequently updated.

The 1:50 000 claim map for NTS 21 O/8 map area will be digitized manually. A conversion program will be made to transfer the Claim Tracking System to the alphanumeric database of the system.

**MINING LEASES AND RECLAMATION (Step 11)**

Mining lease boundaries and reclamation plans are usually plotted on 1:50 000 maps. Mining plans for past and present mines are available at various scales. There is only one existing mine within NTS 21 O/8. Maps showing mining leases, mining, and reclamation plans will be digitized manually.

**BIBLIOGRAPHICAL DATA (Step 12)**

Bibliographic references for New Brunswick geological publications are available on a MULTIMATE word-processing package. The references for 21 O/8 will be retrieved from the New Brunswick Reference File. A conversion program is necessary in order to convert from the existing software package to the alphanumeric database of the system (INGRES).

**DEVELOPMENT OF AN INTEGRATED SYSTEM OF SPATIALLY REFERENCED DATA (Step 13)**

The integration of the above digitized files and associated alphanumeric database will form a framework for the Geoscience Information System. The integrated system will be tested to allow the following output:

1. Creation of documents identical to the original ones;
2. Merging of display files;
3. Retrieval of graphic elements from the merged display files;
4. Data retrieval according to search conditions;
5. Production of various drawings with a pen plotter and copies from a colour screen.

**SPATIAL ANALYSIS AND MODELLING (Step 14)**

Spatial analysis involves combining data from multiple spatial data sets (geology, geophysics, mineral occurrences, etc.), and performing spatial analysis techniques and modelling on the GIS data sets to transform the data into information suitable for a given purpose. As an example, if an exploration company is looking for exploration targets, data sets containing

geology, geophysics, geochemistry, mineral occurrences, and mineral deposits should be combined in order to retrieve the data having the best coincidental anomalies.

**DEMONSTRATION AND PRESENTATION (Step 15)**

The pilot project will be carried out in close cooperation with geologists, engineers, and computer scientists. In order to receive continuous feedback, a demonstration of the system and output at all stages is essential.

After the initial digitization of various data sets, a demonstration will be given to department personnel. Any suggested changes would then be made to the system. A further demonstration would be given to exploration and mining companies operating in New Brunswick.

The system is expected to be ready by October 1990 and, if so, it will be demonstrated at the Minerals and Energy Division Fifteenth Annual Review of Activities. However, if a major part of the system is ready for demonstration by March 1990, it will be presented at the Prospectors and Developers Convention in Toronto.

**DOCUMENTATION (Step 16)**

The system will be documented and published as a Topical Report, and will be available from the Minerals and Energy Division of the New Brunswick Department of Natural Resources and Energy.

## MINERAL EXPLORATION STIMULATION PROGRAM (MESP)

G.W. Crouse, MESP Coordinator

MESP provides financial assistance to mineral exploration companies and prospectors who would like to carry out exploration for minerals within the Province of New Brunswick.

MESP is a direct private sector assistance program offered by the Department of Natural Resources and Energy. The program was first offered in 1988 and due to its popularity was continued in 1989.

A committee of government and private sector representatives reviews applications for MESP grants and, if approved, up to $3 000.00 per prospector is available. The committee members are R.R. Irrinki, L.R. Fyffe, A.A. Ruitenberg, S.R. McCutcheon, D. Hoy, and G.W. Crouse. Eligible work would include: regional and detailed prospecting, grid establishment, geological mapping, geophysical and geochemical surveys, trenching and drilling, assays and chemical analysis, and specialized work such as mineralogy.

The committee reviewed 22 applications and approved 14 for funding. A total of $30 000.00 was approved.

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PSEM donne une aide financière aux sociétés d'exploration et prospecteurs voulant rechercher des minéraux au Nouveau-Brunswick.

Le programme de stimulation de l'exploration minière est un programme direct d'aide au public offert part la Service des Ressources naturelles et d'Energie. Le programme a vu le jour en 1988 et, à cause de sa réception populaire, a été poursuivi en 1989.

Un comité de représentants du gouvernement et du publique étudie les demandes pour l'aide PSEM et, si acceptées, jusqu'à 3 000,00 $ par prospecteur est disponible. Les membres du comité sont R.R. Irrinki, L.R. Fyffe, A.A. Ruitenberg, S.R. McCutcheon, D. Hoy, et G.W. Crouse. Compris dans les travaux acceptables sont: la prospection régionale et détaillée, préparation d'une grille, cartographie géologique, géophysique, ou géochimique, tranchées et sondages, analyses à feu et chimiques, et des travaux spécialisés comme la minéralogie.

Le comité a étudié 22 demandes et en a approuvé 14, pour une somme totale de 30 000,00 $ en octrois.

## DRILL-CORE MANAGEMENT PROGRAM

G.W. Crouse, Core Manager

Approximately 5 000 metres of core was collected by the New Brunswick Department of Natural Resources and Energy this year. Most of the core was delivered to the Madran storage facility northwest of Bathurst.

The storage sheds started last summer with the aid of MDA funds were completed this year and approximately 120 000 m of core was moved into them.

Core was moved into the new storage facility at the Hugh John Forestry Complex in Fredericton and the facility has received numerous visitors since its opening.

The drill-core database is still being appended.

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Environ 5000 metres de carots de forages ont été collectionés par la Service des Ressources Naturelles et d'Energie cette année. La plupart des carots est emmagasinée au dépôt a Madran, nord-ouest de Bathurst.

Les batisses d'entreposage, entrepris l'été passe avec l'aide des fonds MDA (EDM in french) ont été achievées cet année, et on y a entrepose environ 120 000 m de carots.

Des carots ont été demenages au dépôt nouveau a l'Ensemble forestier Hugh John a Fredericton, et ce dépôt des visiteurs nombreux depuis son ouverture.

La base de données sur les carots est ouverte.

# MURRAY BROOK SULPHIDE DEPOSIT STUDY, RESTIGOUCHE COUNTY, NEW BRUNSWICK

Paul Rennick, Project Geologist

The Murray Brook deposit and its gossanous cap are owned by NovaGold Resources Inc. The sulphide deposit and overlying gossan have been evaluated by surface diamond drilling. Computerized databases have been compiled from available drill-hole data.

Detailed mapping on a 1:10 000 scale was carried out during the 1989 field season. Drill core was relogged and sampled. As a result of this mapping project, two new sulphide occurrences were discovered. The first, a massive sulphide body, occurs approximately 1400 m southeast of the Murray Brook deposit at longitude 66°25'01" and latitude 47°31'02". The second discovery, consisting of semi-massive pyrite, is located approximately 500 m east of the Murray Brook deposit at longitude 66°25'31" and latitude 47°31'37".

Drill-hole plans, longitudinal sections, and cross-sections of the Murray Brook deposit have been constructed using updated drill-hole database files.

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Le gisement de Murray Brook et son chapeau férrugineux appartiennent à Nova Gold Resources Inc. Le dépôt de sulfure et le chapeau férrugineux qui le surplombe ont été évalués au moyen de forages au diamant. Les données des forages ont permis l'établissement de bases de données informatisées.

Un relevé cartographique détaillé, à l'échelle 1:10 000, a été effectué pendant la saison sur le terrain de 1989. Un nouveau journal de sondage et un échantillonnage des carottes de forage ont été réalisés. À la suite de ce projet cartographique, deux nouveaux gisements de sulfure ont été découverts. Le premier, une lentille massive de sulfure, se trouve à environ 1 400 mètres au sud-est du gisement de Murray Brook à la longitude 66°25'1" et à la latitude 47°31'02". La seconde découverte, une pyrite semi-massive, est située à environ 550 mètres à l'est du gisement de Murray Brook à la longitude 66°25'31" et à la latitude 47°31'37".

Les plans de forage, les sections longitudinales et transversales du gisement de Murray Brook ont été établis en utilisant les indications de la base de données des forages préalablement mise à jour.

## INTRODUCTION

The Murray Brook sulphide deposit (Figure 11) is being evaluated as part of a comprehensive study of base-metal deposits in northern New Brunswick. All available drilling data has been compiled into computerized databases. During the 1989 field season, all available drill core was relogged and representatively sampled. Geological mapping at a scale of 1:10 000 was completed during July and August, 1989.

## LOCATION AND HISTORY

The Murray Brook deposit is located in the Tetagouche Lakes map area (NTS 21 O/9), approximately 80 km west of Bathurst,

New Brunswick in Restigouche County. Geological maps are available on both the regional (Helmsteadt 1971) and local scale (Jones 1962; Fyffe 1973).

The deposit was discovered by Kennco Exploration in 1956, and was outlined by diamond drilling in 1957 (Perusse 1958; Fleming 1961). From 1960 to 1970, intermittent drilling was done to test the limits of the deposit (Dearden 1964). During 1974/75, a drilling program was carried out by Canex Placer to test the metallurgy of the massive sulphides (Shklanka 1975). From 1985 (Pitman 1985) to 1989, drilling has been carried out to test the gossanous cap and underlying copper-rich sulphides.

## GEOLOGY

The Murray Brook map area (Figure 13) is underlain by polydeformed Ordovician sedimentary, felsic and mafic volcanic rocks of the Tetagouche Group. These rocks have been intruded by gabbro, diabase, and quartz-feldspar porphyry of probable Ordovician age. Late Silurian conglomerates unconformably overlie the Ordovician sequence.

Quartzose Sedimentary Rocks (Unit Os): Quartzite, quartzose siltstone, and minor phyllitic siltstone occur in the southwestern part of the map area, which are thinly interbedded (10-20 cm thick).

Massive Sulphides (Unit Oms): There are three occurrences of massive sulphides in the area. The Murray Brook deposit is a large body of massive pyrite with associated sphalerite, galena, and chalcopyrite occurring in quartzose siltstone. A newly discovered massive sulphide lens in the same horizon, is located approximately 1400 m southeast of the Murray Brook deposit at longitude 66°25'01" and latitude 47°31'02". Another new discovery, comprising semi-massive pyrite in contact with mafic volcanics, is exposed 500 m east of the Murray Brook deposit, at longitude 66°25'31" and latitude 47°31'37".

Felsic Volcanic Rocks (Unit Ofv): Felsic volcanic rocks occur stratigraphically above the sedimentary rocks of Unit Os. Massive to foliated quartz-feldspar porphyry underlies the area to the south of the northeast-trending sediments. Felsic tuff, rhyolite, and minor siltstone are present on the north side of Unit Os. Rhyolite and felsic tuff also occur along the eastern boundary of the map area.

Foliated Mafic Volcanic Rocks (Unit $Omv_1$): Mafic volcanics occur above Unit Ofv and in fault contact with Unit Os. This unit consists predominantly of foliated mafic flows and tuffs. Within this unit, there are two distinct rock types that can be identified as marker horizons. A mafic feldspar porphyry occurs near the base of the unit; black to red manganiferous slates (Unit $Omv_{1S}$), occurring at a high

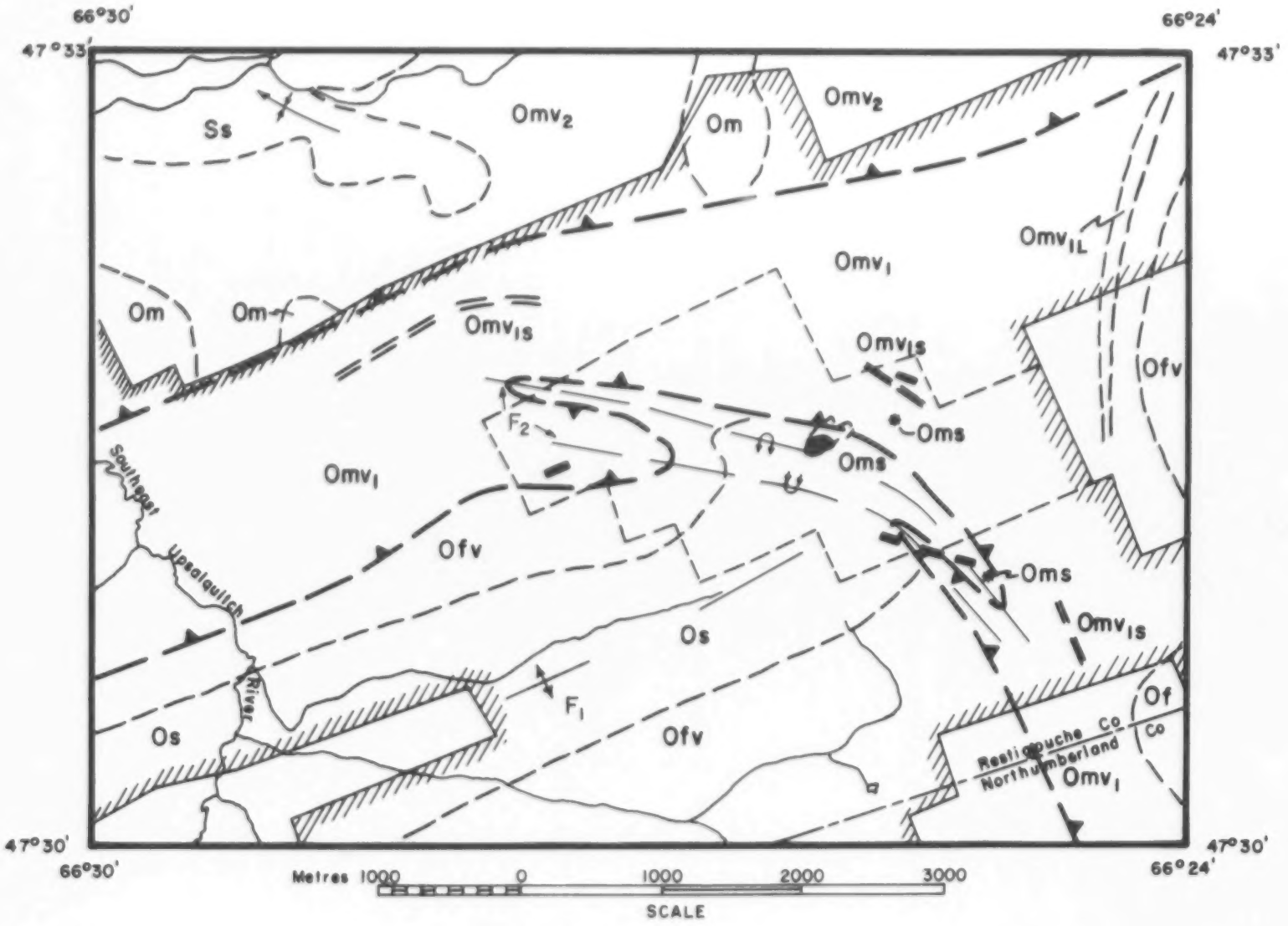


FIGURE 13. Geology of Murray Brook map area (21 O/9 - 101).

## STRATIGRAPHY OF THE MURRAY BROOK MAP AREA (NTS 21 O/9-101)

**LATE SILURIAN**

| | |
|---|---|
| Ss | Red and green conglomerate, sandstone; minor siltstone |

**PRE-LATE SILURIAN**

| | |
|---|---|
| Of | Quartz-feldspar porphyry |
| Om | Gabbro, gabbroic pegmatites, diabase dykes |

**ORDOVICIAN**

| | |
|---|---|
| $Omv_2$ | Massive to pillowed basalt and basaltic breccia |
| $Omv_1$ | Mafic flows and tuffs; minor graphitic and manganiferous slates ($Omv_{1S}$), minor limestone ($Omv_{1L}$) |
| Ofv | Quartz-feldspar porphyry, felsic tuffs, rhyolite; minor siltstone |
| Oms | Massive sulphides |
| Os | Quartzite, quartzose siltstone; minor phyllite and graphitic siltstone |

### SYMBOLS

- County line
- Mineral claim boundaries
- Mining Lease 252
- Geological contact
- Thrust fault
- Sulphide occurrence
- Surface expression of Murray Brook gossan and sulphide body
- Mafic dyke

stratigraphic level, are found interbedded with graphitic slates. A north-trending limestone bed (Unit $Omv_{1L}$) is found in the northeast corner of the map area, within the mafic volcanics.

**Mafic Volcanics (Unit $Omv_2$)**: Massive to pillowed basalt and basaltic breccias underlie the northern part of the map area. These rocks are distinguished from those of Unit $Omv_1$ by the absence of a penetrative cleavage found in rocks to the south. The contact with Unit $Omv_1$ to the south is that of an east-trending fault.

**Mafic Intrusions (Unit Om)**: Gabbro and gabbroic pegmatites intrude mafic volcanics in the northern area of the map. East-trending diabase dykes are found cutting the sediment and mafic volcanics in the central part of the map area.

**Quartz-Feldspar Porphyry (Unit Of)**: A quartz-feldspar porphyry, having a subporphyritic texture, intrudes mafic volcanic rocks in the southeastern corner of the map area.

**Conglomerate (Unit Ss)**: Red and green conglomerate, sandstone, and minor siltstone unconformably overlie mafic volcanics in the northwestern portion of the map area. Cobbles and pebbles of mafic volcanic rocks, gabbro, minor felsic volcanic rocks, and sedimentary rocks are present in the conglomerates. Late Silurian (Ludlovian) age brachiopods (Conchidium; Naylor 1965) are present in red calcareous sandstone south of Eighteen Mile Brook.

The Murray Brook sulphides and related rocks have been subjected to four phases of deformation. The first deformational phase is represented by mineralogical layering is subparallel to bedding. The bedding ($S_0$) and regional foliation ($S_1$) have an east to southeast trend and shallow to moderate northerly dips.

The second deformational phase was that of tight to isoclinal folds ($F_2$) on a mesoscopic to macroscopic scale with an axial planar crenulation cleavage ($S_2$). These cleavages have an easterly to southeasterly trend with moderate to steep, northerly to northeasterly dips, respectively. Thrust faulting along the quartzose sediment mafic volcanic contact occurs parallel to the $S_2$-$F_2$ structures.

The third phase of deformation is represented by north-trending axial planar crenulations ($S_3$) and mesoscopic to macroscopic, north-plunging and steep to vertical open folds. Open folds of similar attitude are present in the Silurian sediments in the northern part of the map area.

The fourth deformational feature is that of east-trending and steep-dipping conjugate kink folds. These are present in

the mafic volcanic rocks east of the Murray Brook deposit and are found on a centimetre scale.

## MURRAY BROOK MASSIVE SULPHIDE DEPOSIT

The Murray Brook deposit has been periodically explored, since the 1956 discovery, by surface diamond drilling (Figure 13). The reserves of the Murray Brook massive sulphides have been estimated to be 23.6 million tons grading 0.44% Cu, 0.86% Pb, 1.95% Zn, and 0.91 oz./ton Ag (Rankin 1981). The objective of the present study is to calculate the reserves of high-grade copper and high-grade lead-zinc present within the massive sulphide body, using computer-generated cross-sections and longitudinal sections.

An oxidized gossanous cap, associated with the massive sulphide body, is estimated to contain 1.67 million tons grading 1.47 oz./ton Ag and 0.037 oz./ton Au. The 1989 drilling program has further delineated the gossan to 1.9 million tons grading 1.91 oz./ton ag and 0.044 oz./ton Au, using a specific gravity of 2.65.

## CONCLUSIONS

The Murray Brook map area is underlain by polydeformed sediments, felsic volcanic, and mafic volcanic rocks of the Ordovician Tetagouche Group. These rocks are cut by mafic and felsic intrusions and later unconformably overlain by Late Silurian conglomerate and sandstone of the Chaleurs Group.

The Murray Brook sulphide deposit occurs within quartzose sedimentary rocks. A precious-metal-enriched oxidized gossan overlies the near-surface portion of the sulphide body.

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**GEOLOGICAL SURVEYS BRANCH**

**BATHURST REGIONAL OFFICE**

# ACTIVITIES OF THE BATHURST REGIONAL OFFICE

S.R. McCutcheon, Regional Geologist

The staff of the Bathurst Regional Office consists of S.R. McCutcheon, (Regional Geologist), J. MacIntosh (Assistant Regional Geologist), S. McKinnon (Administrative Officer), M. Belland and K. Smith (Engineering Technicians), and A. Brewer, M. Parkhill, and J. Walker (MDA contract geologists). The MDA I projects are ready for editing and will be published as Reports of Investigation with accompanying maps. Three new projects, namely Antinouri-Nicholas, Brunswick, and Nepisiguit Lakes, were started this year using the remaining MDA I monies and meager provincial funds. About 4000 m of diamond-drill core from the Half Mile Lake deposit were moved to Madran. A layman's account of the history of the Austin Brook and Brunswick No. 6 deposits was prepared. A talk and poster displays were given on the Brunswick No. 6 host rocks. Advice was given to the Department of Municipal Affairs and Environment on the Newcastle water problem and a number of mineral showings were visited.

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Les employés du Bureau régional de Bathurst sont S.R. McCutcheon (Géologue régional), J. MacIntosh (Géologue régional assistant), S. McKinnon (Cadre d'administration), M. Belland et K. Smith (Techniciens), et A. Brewer, M. Parkhill, et J. Walker (contrat MDA, géologues). Les projets MDA I sont prêts pour l'édition et seront publiés comme Rapports d'investigation avec les cartes accompagnantes. Trois projets nouveaux, soit Antinouri-Nicholas, Brunswick, et Nepisiguit Lakes ont debuté cette année en se servant des fonds MDA I restant et fonds minces provinciaux. Environ 4000 m de carottes au diamant provenant du dépôt de Half Mile Lake ont été démenagés à Madran. Un compte rendu pour l'homme de la rue sur l'histoire des dépôts d'Austin Brook et Brunswick No. 6 a été préparé. Une causerie et une présentation par affiches ont été présentées sur les roches renfermant le Brunswick No. 6. Des conseils ont été donnés au ministère des Affaires municipales et de l'Environnement sur le problème de l'eau à Newcastle, et plusieurs indices minéraux ont été visités.

The staff of the Bathurst Regional Office consists of Steven McCutcheon (Regional Geologist), Jim MacIntosh (Assistant Regional Geologist), Sharon McKinnon (Administrative Officer), Maurice Belland and Kevin Smith (Engineering Technicians). J.A. MacIntosh has been on sick leave since June 2nd. K. Smith is the interim replacement for Andy LeBlanc who has taken a one-year leave of absence. Andrew Brewer, Mike Parkhill, and Jim Walker are contract geologists responsible for projects funded through the Canada-New Brunswick Mineral Development Agreement (MDA I). Because of the uncertainties surrounding MDA II, A. Brewer decided to take a position with industry as of October 1st.

## CANADA-NEW BRUNSWICK MDA I PROJECTS

The Upsalquitch Forks (J. Walker) and Charlo River

(A. Brewer) projects are complete except for editing and publication. Output from the Upsalquitch Forks project will include a Report of Investigation accompanied by a 1:50 000-scale (2-colour) geological map. There will also be twenty-five (25) 1:10 000-scale open file outcrop maps from which the 1:50 000 map was compiled. Output from the Charlo River project will include a Report of Investigation accompanied by seven (7) 1:20 000-scale geological maps. A 1:50 000-scale (2-colour) geological map covering most of the project area (21 0/15E and 21 0/16W) will also be published.

The results of till-mapping projects by M. Parkhill will be summarized in a Report of Investigation. This report will be accompanied by a series of maps at 1:100 000 scale covering 21 0/9, 21 0/10, and 21 0/15.

**PROVINCIAL PROJECTS**

Three new projects were started using the remaining MDA I funds for salaries and provincial funds for field work. The Antinouri-Nicholas project (this volume) was conceived as a 5-year MDA II program to study the mineral occurrences/deposits in the Bathurst and Pointe Verte map areas (21 P/12 and 21 P/13, respectively). A two-person party (J. Walker and S. LeBlanc) was in the field for part of the summer.

The Brunswick project (this volume) is a provincial stratigraphic and lithogeochemical study of igneous and sedimentary rocks associated with the "Brunswick horizon" with the objective being to clarify the internal stratigraphy of the base-metal-bearing rocks. Preliminary sampling was done around the No. 6 open-pit mine last year by M. Belland. This year selected drill cores between No. 6 and No. 12 were logged and sampled by A. Brewer and B. MacEachen. Field work for the above projects was financed from the meager mapping budget of the Bathurst office.

The Nepisiguit Lakes Project is another integrated study that was proposed for MDA II. It includes bedrock mapping and till-geochemical studies of the Nepisiguit Lakes map-area (NTS 21 0/7) to determine the mineral potential of the Mount Sagamook caldera complex (McCutcheon 1989).

The bedrock mapping is being conducted by R. Wilson (this volume), whereas the till study is being done by M. Parkhill (this volume). Field work for the Nepisiguit Lakes project was financed from the Fredericton office.

**DIAMOND-DRILL CORE**

In 1989, 5 holes (totalling 4136.75 m) were transported from on-site storage at the Halfmile Lake massive sulphide deposit to Madran. Thousands of metres of core that still remain at Half Mile Lake will be moved to Madran if and when money is available. The twenty core-storage racks at Madran,

which were under construction last year, have been completed and loaded with core. Most of the core that was on the ground is now in racks.

## OTHER ACTIVITIES

S.R. McCutcheon gave a talk at the Atlantic Geoscience Society Annual Meeting in Amherst describing the petrographic and lithogeochemical evidence that the Brunswick No. 6 massive sulphide deposit is sediment-hosted. The abstract of this talk will be published in Volume 25 of Atlantic Geology. A poster display on the same topic was presented at the Prospectors and Developers in Toronto and the Geological Association of Canada Annual Meeting in Montreal.

Advice was given to the Department of Municipal Affairs and Environment regarding the Newcastle water supply. The new water source is adequate in quantity, but of poor quality due to its high manganese content. Therefore, a water treatment plant was recommended.

Assistance was rendered to Dr. J. Greenough of Mount Allison University, who collected suites of samples for lithogeochemical study from several ancient hydrothermal environments including Turgeon, Brunswick No. 12 and Popelogan. The object of Dr. Greenough's study is to understand the geochemical behavior of platinum-group metals in these environments.

Field trips were made to the following mineral properties: Brunswick Mining and Smelting, Caribou, Corona, Noranda, Nova Gold, Rio Algom, Stratabound Minerals, Westminer Canada, W. Carroll, O. O'Connell, J. Duffy, O. Hickey, and F. Cady. Also, core from a hole drilled by Sharpe Energy and Resources at Bruce Siding was examined and samples were collected for further study.

M. Belland prepared a layman's account of the history of the Austin Brook and Brunswick No. 6 deposits. His manuscript has been submitted for editing and eventually will be published as a Popular Geology Paper.

K. Smith drafted the geological maps for the Upsalquitch Forks project. He also drafted new base maps and made corrections to the geological overlays, for the Charlo River project.

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# ANTINOURI-NICHOLAS PROJECT
# RESTIGOUCHE AND GLOUCESTER COUNTIES, NEW BRUNSWICK (MDA)

S.R. McCutcheon and J.A. Walker

The Antinouri-Nicholas project entails five distinct phases to be conducted under MDA II: 1) mapping and re-logging of drill core, not only to establish the stratigraphic framework, but also to locate and determine the geologic setting of the mineral occurrences/deposits; 2) selection of deposits/samples for detailed analysis including lithogeochemical, petrographic, age dating, fluid inclusion and isotopic studies; 3) compilation of all assessment data; 4) till mapping and geochemistry; and 5) computerization of drill-core data from the known mineral deposits such as Elmtree, Nigadoo, and Turgeon.

Phase one began this summer in the northeastern part of NTS 21 O/9. Preliminary mapping shows that: a) cobble conglomerate (Unit $Ss_4$ in Map NR-3) is distinct from Silurian conglomerates and may be coeval with the Devonian Campbellton Formation; b) mafic and felsic volcanic rocks predate the cobble conglomerate and extend farther south than previously believed; c) there is a vein-type, copper-barite occurrence along the northeast-trending fault that separates Silurian(?) volcanics from Devonian sedimentary rocks near Jacquet River; d) the Silurian sedimentary sequence consists of interbedded green and red siltstone with subordinate sandstone and conglomerate; there are at least three separate conglomerate units; and e) the Rocky Brook-Millstream Fault is not the boundary between Ordovician and Silurian rocks in the map area.

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Le projet Antinouri-Nicholas englobe cinq phases distinctes sous l'égide du MDA II: 1) la cartographie, et l'examen des carotte à forages, dans le but d'établir la stratigraphie et aussi l'environnement géologique des indices et dépôts de minéraux; 2) le choix de gites/échantillons pour des analyses détaillées, y compris des études litho-géochimiques, pétrographiques, d'âges absolus d'inclusions fluides, et d'isotopes; 3) la compilation de tous les travaux d'évaluation; 4) la cartographie et la géochimie des morts-terrains; and 5) mise en ordinateur des données sur les forages et carottes des gites connus, comme ceux de Nigadoo, Elmtree, et Turgeon.

La phase première a débuté cet été dans la secteur du nord-est du STN 21 O/9. La cartographie préliminaire indique que: a) le conglomérat à cailloux (unité $Ss_4$ de la carte NR-3) se distingue des conglomérats d'âge Silurien et pourrait avoir été déposé en même temps que la formation de Campbellton, d'âge Dévonien; b) les roches volcaniques mafiques et felsiques sont plus vieilles que le conglomérat à cailloux et sont connues plus au sud maintentant que jadis; c) il y a un indice de cuivre-barite en veine associée avec la faille à direction de tendance nord-est entre les roches volcaniques d'âges Silurien (?) et les roches sédimentaires d'âge Dévonien proche de la rivière Jacquet; d) la séquence sédimentaire d'âge Silurien est de couches interlitées, vertes et rouges, de pélites avec moins de grès et conglomérat; au moins trois unités distinctes de conglomérat; et e) la faille Rocky Brook-Millstream ne suit pas la limite entre les roches d'âge Silurien et Ordovicien dans la région de la carte.

The Antinouri-Nicholas project, which includes NTS map areas 21 P/12 and P/13 and the eastern parts of 21 O/9 and O/16, was proposed as an MDA II project because of the following factors.

1. A large number (80) of metallic mineral showings occur in the area.
2. A regional gravity low associated with the Antinouri Lake, Nicholas-Denys, and Nigadoo intrusions suggests that they may all be part of the same complex. Many of the mineral occurrences are genetically related to these intrusions, but the important controls on mineralization need to be identified.
3. The large volume of assessment data and drill core that are available from the area need to be compiled, synthesized and set in a stratigraphic framework.
4. The full mineral potential of the area must be realized before development in the area has advanced to a point where it may prevent the opening of new mines.

The project includes five distinct phases:

1. Mapping and relogging of drill core, not only to establish the stratigraphic framework but also to locate and determine the geologic setting of the mineral occurrences/deposits.
2. Selection of deposits/samples for detailed analysis including lithogeochemical, petrographic, age dating, fluid inclusion, and isotopic studies.
3. Compilation of all assessment data.
4. Till mapping and geochemistry.
5. Computerization of drill-core data from the Elmtree, Nigadoo, and Turgeon deposits.

Phase one of the Antinouri - Nicholas project was started this spring using provincial funds and with the hope that MDA II would be signed shortly. Field work was begun in the northeastern part of 21 O/9 where the stratigraphy is poorly known; it is also the only area with 1:10 000-scale base-map coverage (Figure 14).

Mapping was carried out in the area of Lower South Branch Jacquet River and its eastern tributaries (NTS 21 O/9h). This area is covered by parts of six 1:10 000-scale maps, namely 304, 305, 404, 405, 504, and 505. Several samples have been taken for petrographic analysis. Several drill cores from Acadia's Millstream - West property were logged for stratigraphic information.

Geological problems that require investigation are:

1. The stratigraphy of the belt of Silurian rocks that separates the Elmtree Terrane from the Tetagouche Group to the south.

2. The stratigraphy of rocks bordering the Elmtree Terrane to the west.
3. Structural features controlling the distribution of mafic dykes, particularly those that are auriferous.
4. The location of the Rocky Brook-Millstream Fault with respect to the boundary between Ordovician and Silurian rocks.
5. The nature of the contact between the western end of the Ordovician Elmtree Terrane and the adjacent Siluro-Devonian rocks to the west and south.
6. The possible southward extension of the Jacquet River Fault based on the gradiometer data.
7. The western extent of contact-metamorphic effects associated with the Antinouri-Nicholas intrusive complex.

Results of the 1989 mapping project are:

1. The mapping suggests that cobble conglomerate (Unit $Ss_4$ on map NR-3) to the immediate west of the Elmtree Terrane is in unconformable contact with the Ordovician and Silurian rocks, and post-dates the emplacement of the mafic dykes. This conglomerate is lithologically distinct from those of the Chaleurs Group to the south and it may be coeval with the Middle Devonian Campbellton Formation.
2. In addition to sedimentary rocks there are mafic and felsic volcanics (probably Chaleurs Group) and mafic intrusions immediately west of the cobble conglomerate.
3. The volcanic pile, mentioned above, is separated from Devonian sedimentary rocks along Jacquet River by a major northeast-trending fault. A vein-type, copper-barite occurrence has been found along this fault.
4. Core logging has revealed that the belt of Chaleurs Group rocks to the south of the Elmtree is composed of inter-bedded green and red siltstones, minor sandstones and conglomerates. There are at least three conglomerates, all of which can be distinguished locally by the lithology and roundness of the clasts. The conglomerates are not basal but appear to be basin-margin facies.
5. The Rocky Brook-Millstream Fault is not the boundary between Ordovician and Silurian rocks in the map area.

**NOTE:** Figure 14 and legend are on following pages.

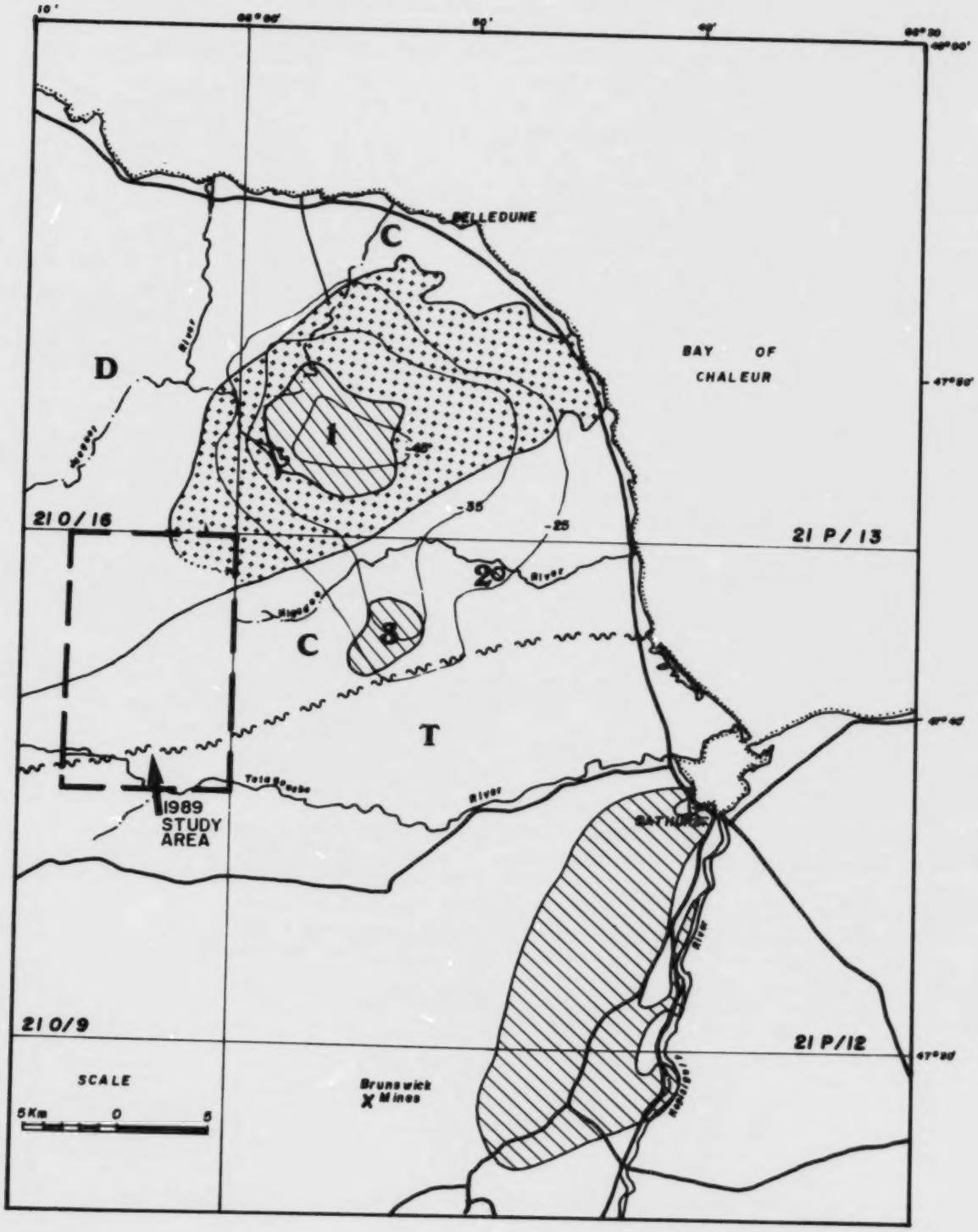
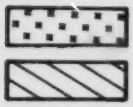



FIGURE 14. Simplified geology map of the Antinouri-Nicholas project area showing the location of the 1989 field mapping.



ELMTREE TERRANE

FELSIC INTRUSIONS

1. Antinouri Lake

2. Nigadoo

3. Nicholas – Denys

D DALHOUSIE GROUP (mainly)

C CHALEURS GROUP (mainly)

T TETAGOUCHE GROUP (mainly)

ROCKY BROOK-MILLSTREAM FAULT

-36- GRAVITY CONTOUR (milligals)

# SURFICIAL GEOLOGY AND TILL GEOCHEMISTRY OF THE NEPISIGUIT LAKES MAP AREA (NTS 21 O/7), NORTHUMBERLAND AND RESTIGOUCHE COUNTIES, NEW BRUNSWICK (MDA)

M.A. Parkhill, Project Geologist

The surficial geology of the Nepisiguit Lakes map area (NTS 21 O/7) was mapped at a scale of 1:50 000 during 1989. Basal till and soil were sampled at 264 sites on a 2 km grid. Soil profile descriptions and vegetation inventories were prepared. The samples will be analysed for Au plus 33 other elements, and selected base metals.

Striated bedrock, grooves, roche moutonnée, and a till fabric indicate an early eastward ice movement followed by northeastward-flowing ice, north of Mount Carleton. In the southern part of the study area, eastward-moving ice was followed by southeastward- and northeastward-flowing ice. Minor late-stage, local ice flows in various directions followed throughout the area.

Most of the area is covered by a thin layer (<2 m) of Late Wisconsinan basal till, ablation till, or ablation lag over basal till. Around Bathurst and Nictau lakes and in the major rivers and brooks, glaciofluvial and alluvial deposits are common. Bedrock and colluvium dominate in steep valleys and on many mountains and ridges in the area.

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La géologie des morts-terrains de la région Nepisiguit Lakes (STN 21 O/7) a été cartographiée à l'échelle de 1:50 000 en 1989. La moraine de fond et le sol ont été échantillonés à 264 points sur un quadrillage à 2 km. Des profils du sol et inventaires de la végétation ont été faits. On fera les analyses pour l'or, 33 autres éléments et aussi des métaux de base selectionnés.

Le socle strié, sillons, roche moutonnée et la fabrique de la moraine indiquent que la glace s'est déplacée vers l'est et puis, au nord du mont Carleton, ves le nord-est. Dans la partie sud de la région étudiée, la glace se deplaçant vers l'est a été suivie par de la glace coulant vers le sud-est et le nord-est. Des étapes mineures tardives, locales, de déplacements de glace, en directions diverses, ont suivi à travers la région.

La plupart de la région est couverte par une mince couche (<2 m) d'âge Wisconsinien tardif de moraine de fond, moraine d'ablation, ou moraine d'ablation au dessus de la moraine de fond. Autour des lacs Bathurst et Nictau, et dans les lits des rivières et ruisseaux principaux, des dèpôts glaciofluviaux et alluviaux sont communs. Le socle et le talus prédominent dans les vallées à murs raides et sur beaucoup de montagnes et arêtes de la région.

During the summer of 1989, a surficial mapping and till sampling (one sample per 4 $km^2$) program was carried out on a 1:50 000-scale in the Nepisiguit Lakes (NTS 21 O/7) map area. The Nepisiguit Lakes map area lies in north-central New Brunswick, 60 km west of Bathurst along Highway 180 and 30 km northeast of Riley Brook along Route 385 (Figures 15 and 16). A total of 264 sites was sampled (B- and C-horizons). In addition, vegetation inventories and soil profile descriptions were recorded for forest-site classification purposes.

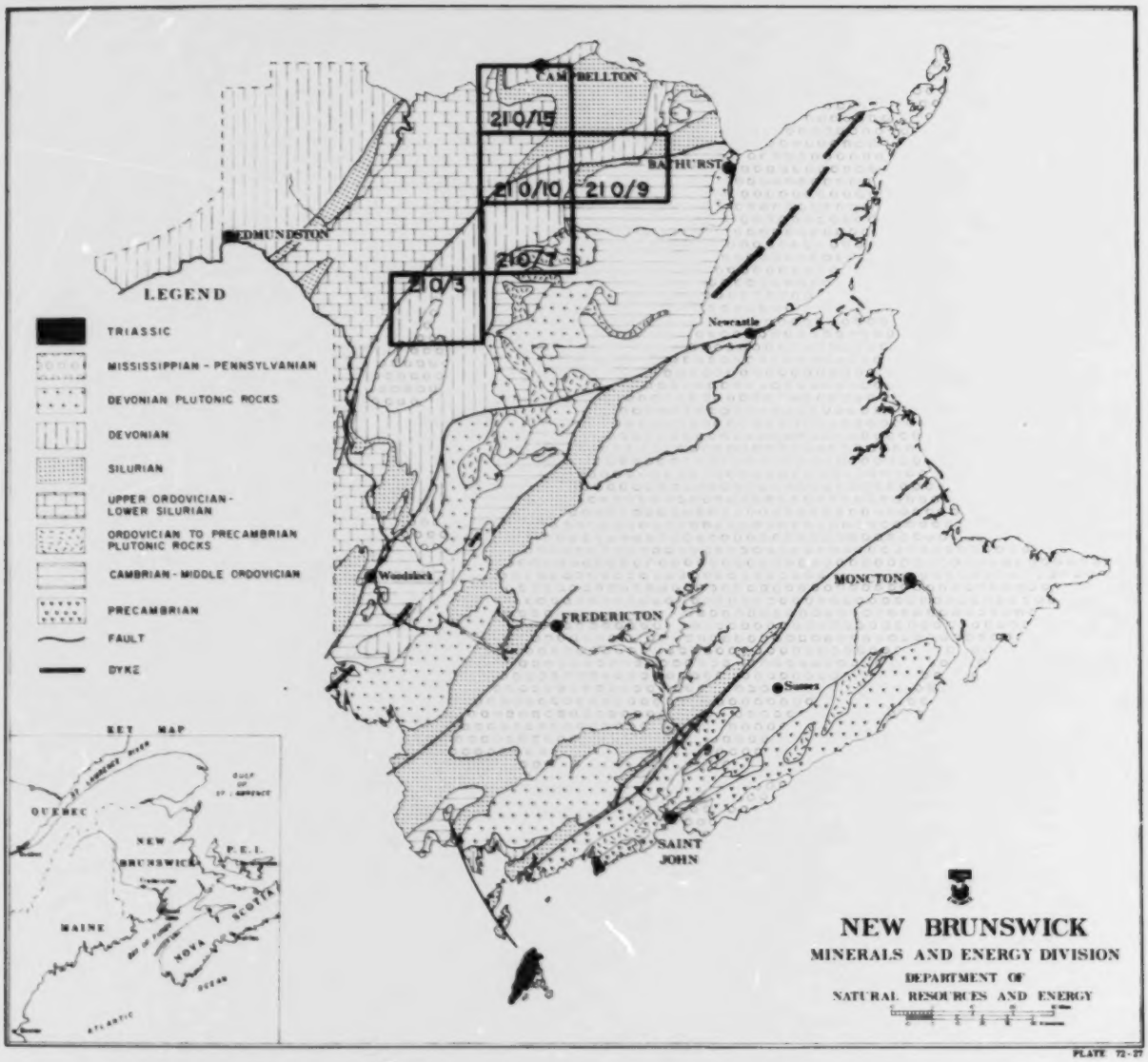


FIGURE 15. Location of surficial geology - till geochemistry projects in northern New Brunswick (1985-1989).

The Nepisiguit Lakes area was selected for study because of its proximity to previously mapped areas (Figure 15), similarities in bedrock geology and simultaneous bedrock mapping of the Tobique Group by Reg Wilson (this volume). The study area was previously mapped and sampled by Allen Seaman as part of the aggregate resources inventory (Seaman 1984). This year's project increased the sample density of the 1983 project and mapped numerous new access roads. Peter Hilder, Colin Reynolds, and Andrew Steeves assisted in the 1989 mapping.

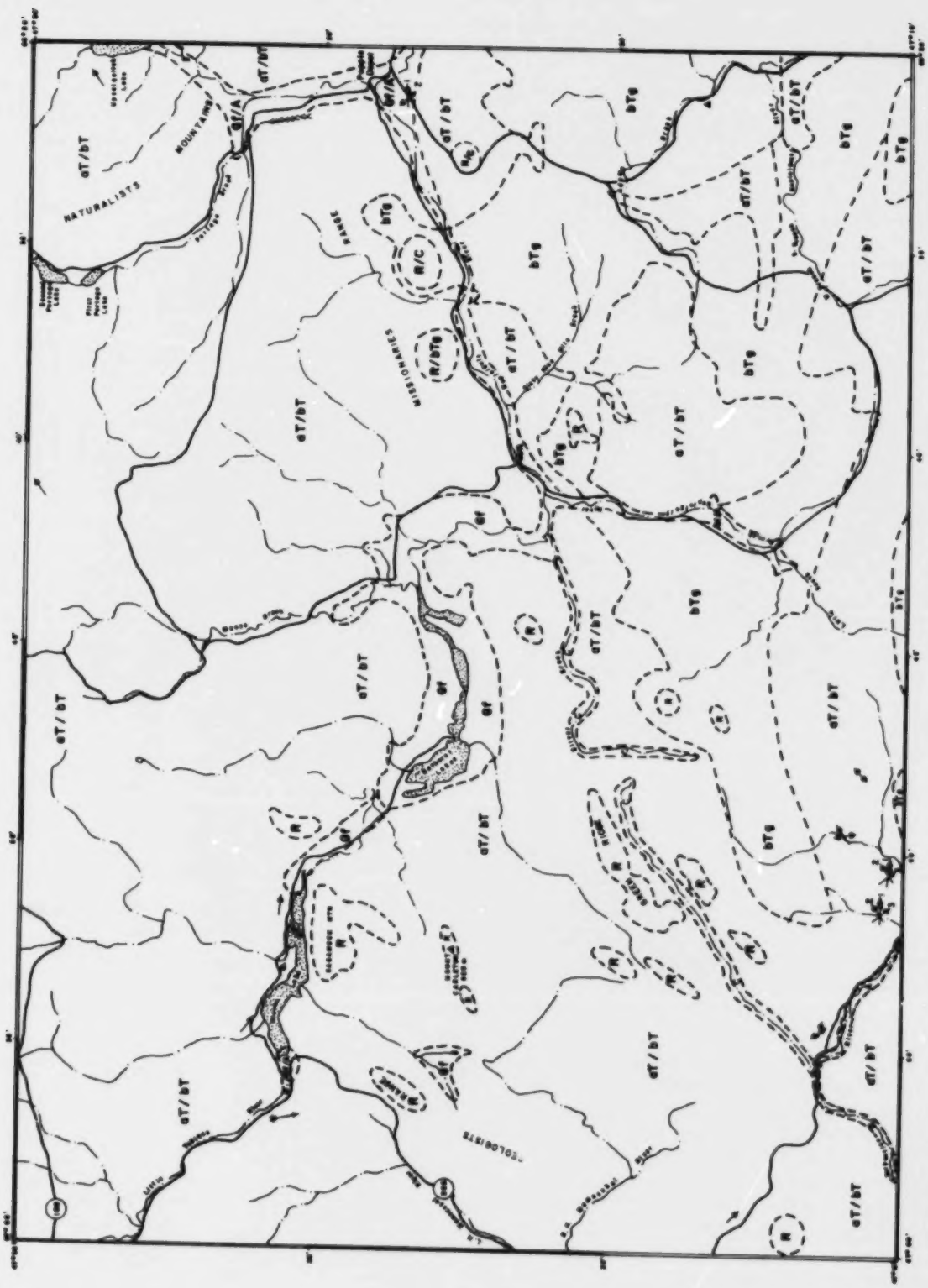


FIGURE 16. Preliminary surficial geology of Nepisiguit Lakes map area (21 O/7).

## LEGEND

| AGE | UNIT | DEPOSIT |
|---|---|---|
| **QUATERNARY** | | |
| HOLOCENE | C | Colluvial |
| | A | Alluvial (sand and gravel) |
| LATE WISCONSINAN | Glaciofluvial | |
| | Gf | Outwash and ice-contact (mainly sand and gravel, minor cobbles and boulders, may be stratified). |
| | Glacial | |
| | aT/bT | Morainal sediments (mainly basal till, minor ablation till and in places ablation lag over basal till; generally thin (<2m), greenish to yellowish brown and brown, fine to coarse, sandy/gravelly to sandy/clayey/loamy tills). |
| | bTg | Basal till/coarse sandy granitic till; discontinuous over deeply weathered bedrock (grus) and bedrock. |
| **PRE-QUATERNARY** | | |
| | R | Bedrock |

## SYMBOLS

- Major access roads
- Major rivers and streams
- Glacial striae (direction known, unknown)
- Relative age of striae (1) older, (2) younger
- Roche moutonnée
- Esker
- Morphogenetic boundary
- Boulder erratic
- Till fabric

Topography is strongly bedrock controlled with deeply incised v-shaped valleys and high mountains, including Mount Carleton the highest point in the Maritime Provinces at 820 m above sea level. Local relief is up to 550 m.

The glacial history of the area is consistent with other areas mapped to the north (NTS 21 0/10; Pronk 1987), and to the southeast (NTS 21 0/3; Pronk and Parkhill 1989). Striated bedrock, grooves, and roche moutonnée suggest a strongly erosive eastward ice movement (080°-110°) as being the earliest. This was followed by northeastward-flowing ice (030°-060°) north of Mount Carleton and the Nepisiguit River, as in the Upsalquitch Forks map area (NTS 21 0/10). In the southern part of the Nepisiguit Lakes map area, as in the Riley Brook map area (NTS 21 0/3), the major eastward movement was followed by southeastward- (130°-165°) and northeastward- (040°-060°) flowing ice. Late-stage, local northward- and southward-flowing ice follows as the last ice movement. Ice movement was affected by topography as evidenced by striae on the north side of Nictau Lake. Ice flowing southeast (127°) gradually shifted to a more eastward direction (098°) as it came in contact with Sagamook Mountain.

Periglacial features, such as the tors on Sagamook Mountain, indicate that the highest elevations may have been a nunatak zone, i.e., above and surrounded by ice. This suggests that the Highland peaks were deglaciated first, subjecting them to periglacial weathering.

Canadian Shield erratics are not found in the Nepisiguit Lakes area, suggesting that Laurentide ice did not move into the Northern Miramichi Highlands.

Glacial deposits include a generally thin layer of sandy/clayey greenish to yellowish brown and brown basal till that is found throughout the area. The till is notably present on high plateaus, e.g., the area between Mount Carleton and Sagamook Mountain. This indicates that the entire area was glaciated at some point during the Late Wisconsinan. The tills are generally locally derived, however some distal clasts are present. In the southeastern part of the area, where granite bedrock is common (Whalen 1988), a coarse sandy granitic till is prevalent (Unit bTg, Figure 16). Deeply weathered bedrock (grus) is common in this area, locally overlain by basal till.

The high peaks in the study area are outcrop or rock veneer and colluvium, with locally patchy till. The steep valley slopes are generally covered with colluvial material. Ablation till occurs as a thin lag over basal till or as a thicker deposit restricted to river and stream valleys.

Deposits of glaciofluvial outwash and ice-contact kames and eskers are found in river and stream valleys and as large deposits around Bathurst and Nictau Lakes. Recent alluvial deposits also occur in many of the rivers and brooks.

Pebble counts and aerial photograph interpretation will be completed to produce a surficial geology and till composition map, useful for both geochemical exploration and forestry applications. All basal till (C-horizon) samples will be analysed for Au plus 33 elements and selected base metals. Surficial geology and till geochemistry maps will be produced in a similar format to Geological Notes Series PM 89-71.

## REFERENCES

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SEAMAN, A.A. 1984. Granular aggregate resources, Nepisiguit Lakes (21 O/7). New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Plate 84-450.

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# BRUNSWICK PROJECT, GLOUCESTER COUNTY, NEW BRUNSWICK

S.R. McCutcheon, A. Brewer, and M. Belland

The Brunswick project is part of a long-term provincial study (not MDA) to determine the depositional and stratigraphic settings of the major massive sulphide deposits in the Bathurst camp. The project was started last year near Brunswick No. 6 and continued this year near No. 12.

The Brunswick No. 6 and No. 12 deposits are underlain by chlorite schist (CS), quartz-augen schist (QAS) and quartz-feldspar-augen schist (QFAS) in descending stratigraphic order. Lithogeochemistry shows that the QFAS near No. 6 is compositionally uniform and comparable to average rhyolites; petrography shows that the QFAS is a lava rather than a pyroclastic flow. The QAS and CS are compositionally variable but similar to sandstones and mudrocks. Petrographic features are compatible with this interpretation. A sedimentary origin for the QAS and CS has important implications.

The post-ore stratigraphy at No. 12 differs from that at No. 6. At No. 12, the rocks include siltstone, re-sedimented hyalotuff, wacke, and minor conglomerate that in at least one locality contains massive sulphide clasts; unequivocal felsic volcanic rocks are virtually absent. At No. 6, felsic volcanic rocks are common in the post-ore sequence and are mainly aphyric or sparcely porphyritic rhyolites; true pyroclastic rocks are sparse. The absence of rhyolites in the post-ore sequence at No. 12 and their abundance at No. 6 indicates that rhyolites (domes) are laterally equivalent to sedimentary rocks and probably the source of the hydrothermal fluids that deposited the massive sulphides.

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Le projet Brunswick fait partie d'une étude prolongée, provinciale (en dehors du MDA) à établir la nature de la déposition et stratigraphie des principaux dépôts de minéraux à sulfure massifs dans le camp minier de Bathurst. Ce projet a débuté l'an passé proche de la mine Brunswick No. 6, et s'est poursuivi cette année proche du No. 12.

Les dépôts No. 6 et No. 12 sont superposés sur un schiste à chlorite (CS), un schiste à augen à quartz (QAS) et un schiste à augen à quartz-feldspath (QFAS) en ordre stratigraphique déscendant. La litho-géochimie montre que le QAS proche du No. 6 a une composition uniforme et comparable au rhyolite moyen; la pétrographie démontre que le QFAS est une lave plutôt qu'une coulée pyroclastique. Les QAS et CS ont une composition variable mais semblable aux grès et argillites (mudrocks). Les données pétrographiques sont compatibles avec cette interprétation. Une source sédimentaire pour le QAS et le CS mène à des implications importantes.

La stratigraphie post-minerai au No. 12 n'est pas semblable à celle du No. 6. Au No. 12 il y a des pélites, hyalo-tuff re-sédiment, grauwacke et conglomérat mineur qui, au moins à une localité, renferment des fragments de sulfure massif; des roches volcaniques felsiques sans équivoque sont presque inconnues. Au No. 6 des roches volcaniques felsiques abondante dans la séquence post-minerai et sont principalement aphyriques ou faiblement porphyriques; les roches pyroclastiques véritables sont rares. Le manque de rhyolites dans la séquence post-minéralisation au No. 12 et leur abondance au No. 6 indiquent que les rhyolites (domes) sont l'équivalents latéraux aux roches sédimentaires et probablement la source des fluides hydrothermaux qui ont déposé les sulfures massifs.

In 1988, a pilot lithogeochemical sampling program was conducted around the Brunswick No. 6 massive sulphide deposit to help determine the lithologic nature of the footwall rocks. The geochemical results are summarized here.

The Brunswick No. 6 Pb-Zn deposit lies within the Ordovician Tetagouche Group (Figure 17). The deposit is underlain by "quartz-feldspar-augen schist" (QFAS), quartz-augen schist" (QAS), and "chlorite schist" (CS) in ascending stratigraphic order, i.e., the CS immediately underlies massive sulphides. The lithogeochemistry (Table 3, Figure 18) shows that the QFAS is compositionally uniform and comparable to average rhyolites in $SiO_2$, $Al_2O_3$, CaO, and $K_2O$. Total iron (as $Fe_2O_3$) $TiO_2$, and MgO are high, whereas $Na_2O$ is low by an order of magnitude. The low $Na_2O$ results are an alteration effect, but the high $TiO_2$ is probably a primary feature. The QAS and CS are compositionally variable but are similar to sandstones and mudrocks, respectively, particularly in their $SiO_2$, $Al_2O_3$, and $K_2O$ contents (Figure 18). The iron to iron-plus-magnesium ratio (F/F+M) is higher in the QAS and CS than in the QFAS, whereas Sr is lower (Figure 19). Also the Th to $TiO_2$ ratio is lower in the CS than in either the QFAS or QAS.

There are similarities and differences in the rare-earth-element (REE) profiles from the three rock types (Figure 20). Profiles from the QFAS (top) are all very similar and exhibit light-REE enrichment relative to heavy-REE. There is also a distinct negative-Eu anomaly. Profiles from the coarse-grained and fine-grained QAS are virtually identical (only the coarse-grained ones are shown; middle) and both are similar, though more variable than those from the QFAS. Profiles from the CS (bottom) show that it has a higher heavy-REE content (apart from the two altered samples) than the other rock types.

The chemistry shows that the QFAS is of igneous origin but the unit is considered to be a lava flow rather than a pyroclastic unit. This is because thin sections show that the QFAS has well-preserved, embayed-volcanic-quartz and lacks angular quartz fragments. These features are indicative of a low-explosivity eruption mechanism, i.e., a lava flow. The chemistry suggests that the QAS is of sedimentary origin. This is supported by two petrographic observations. First, feldspars or their pseudomorphs are easily recognized in the QFAS, but are absent in the QAS. Second, quartz grains in the QAS are generally subrounded and lack the amoeboid outlines of volcanic quartz. These observations are most readily explained by pre-depositional weathering effects, rather than post-depositional processes.

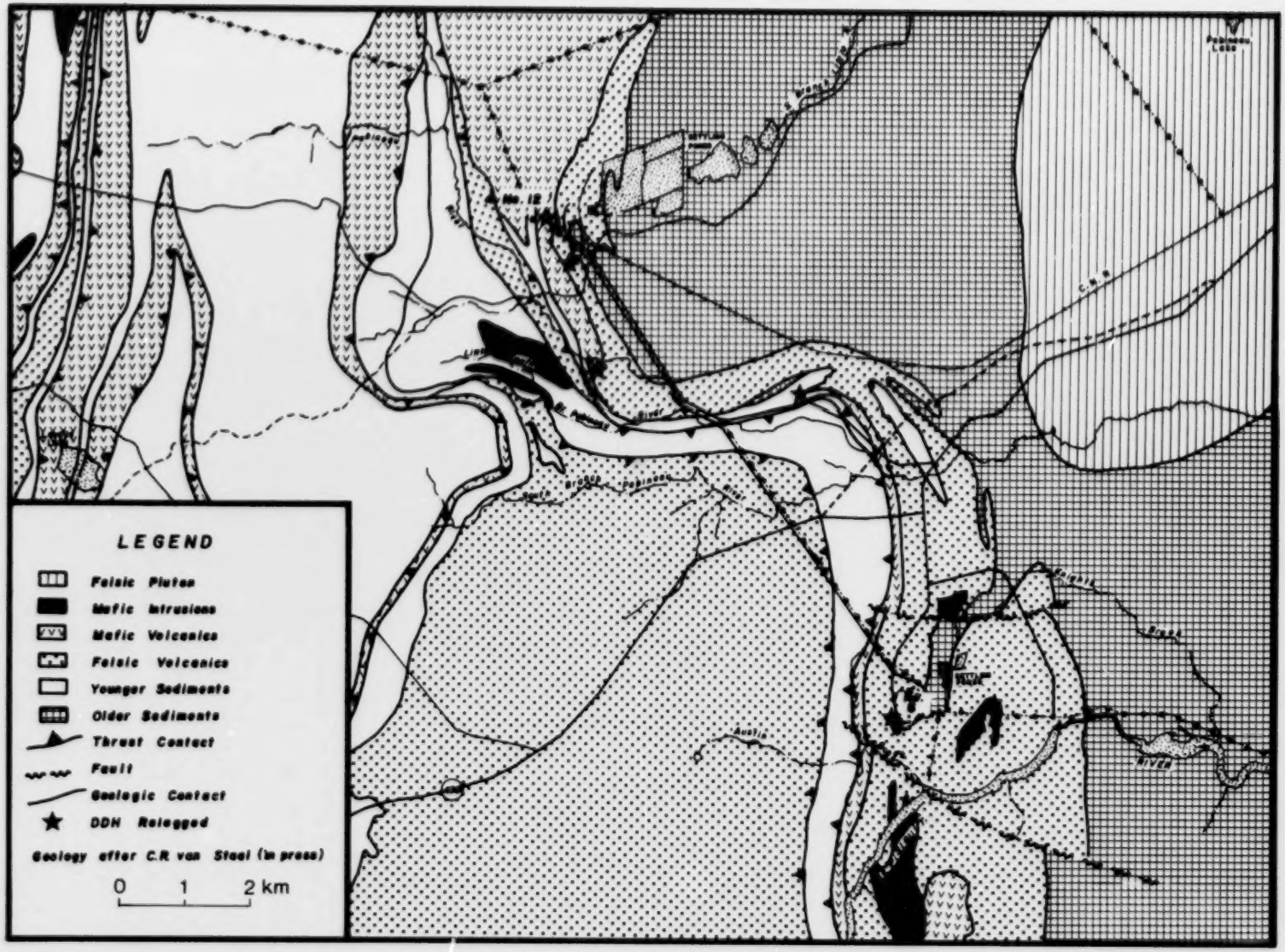


FIGURE 17. Simplified geological map of the Brunswick No. 6 - Brunswick No. 12 area.

TABLE 3 - COMPOSITIONAL RANGES OF ROCKS FROM BRUNSWICK NO. 6 AREA

| | "Chlorite Schist"(n=5) | "Quartz-Augen Schist"(n=11) | "Quartz-Feldspar Augen Schist" (n=5) |
|---|---|---|---|
| $SiO_2$ | 51.5 - 66.5 | 60.7 - 74.1 | 71.2 - 72.0 |
| $TiO_2$ | 0.54 - 1.09 | 0.38 - 0.88 | 0.5 - 0.54 |
| $Al_2O_3$ | 11.0 - 19.5 | 10.8 - 15.3 | 12.9 - 13.5 |
| $Fe_2O_{3T}$ | 9.0 - 18.0 | 6.2 - 14.2 | 3.16 - 3.56 |
| MgO | 1.29 - 4.67 | 0.85 - 3.31 | 1.25 - 1.87 |
| CaO | 0.05 - 0.35 | 0.13 - 0.21 | 0.35 - 0.44 |
| $Na_2O$ | 0.04 - 0.06 | 0.03 - 0.06 | 2.05 - 2.87 |
| $K_2O$ | 1.09 - 5.17 | 1.94 - 2.74 | 3.93 - 4.34 |
| | Mudrocks (n=894) | Sandstones (n=208) | Rhyolites (n=343) |
| $SiO_2$ | 3.4 - 60.2 | 66.1 - 77.1 | 71.1 - 75.9 |
| $TiO_2$ | 0.5 - 0.8 | NO DATA | 0.14 - 0.40 |
| $Al_2O_3$ | 3.8 - 17.3 | 8.1 - 15.1 | 13.1 - 15.1 |
| $Fe_2O_{3T}$ | 5.7 - 7.9 | 2.3 - 6.6 | 1.3 - 2.5 |
| MgO | 2.1 - 2.7 | 0.5 - 2.4 | 0.2 - 0.6 |
| CaO | 1.4 - 6.0 | 0.6 - 6.2 | 0.7 - 2.0 |
| $Na_2O$ | 1.0 - 1.8 | 0.9 - 3.1 | 3.6 - 3.8 |
| $K_2O$ | 2.6 - 3.7 | 1.3 - 2.9 | 4.3 - 4.9 |

NOTE: Mudrock and sandstone data from Blatt, Middleton, and Murray (1971); and rhyolite data from Ewart (1979) are provided for comparison.

There are several important implications if the QAS is of sedimentary origin:

1) Rocks similar to the QFAS, or an unknown coarse-grained granite, were subaerially exposed in order to provide a source of quartz grains that are up to 5 mm in diameter in the QAS.
2) The areal extent of the QAS should be much greater than the QFAS.
3) The QAS was probably deposited in fairly shallow water.
4) The overall decrease in grain size of the QAS going toward the CS either indicates that the water depth became progressively deeper or that the sediment supply was reduced.
5) The massive sulphides were deposited in a low-energy sedimentary environment, although probably along strike from a coeval rhyolite dome (see below).

The chemistry also suggests that the CS is of sedimentary origin (Figure 18). Thin sections show textures that are compatible with this interpretation.

The results of the pilot lithogeochemical study described above indicate that further work of this type is warranted. Therefore, the investigation was expanded in 1989 to include the area between Brunswick No. 12 and Nepisiguit River, namely the band of "felsic volcanics" that lies between mafic rocks (alkali basalts) to the west and the quartzite/slate sequence (older sediments) to the east (Figure 17). Selected drill cores (kindly made available by W. Luff and D. Rutledge of Brunswick Mining & Smelting Corp. Ltd.) were logged for stratigraphic information and sampled for petrographic and lithogeochemical studies.

The following preliminary conclusions are based on logging of core:

1) Massive rhyolites are absent in the stratigraphic pile that overlies massive sulphides (post-ore sequence) at the No. 12 deposit. Most of the rocks that were previously identified as tuffs, are of clastic or epiclastic origin and are interbedded with fine-grained sedimentary rocks.
2) The post-ore sequence constitutes a diverse assemblage of rocks that varies from locality to locality but includes siltstone, re-sedimented hyalotuffs(?), wackes, and minor conglomerate. The conglomerate locally contains massive sulphide clasts.
3) The contact between the post-ore sequence and the overlying mafic volcanics is a high-strain zone and probably a thrust fault.
4) In places, at the stratigraphic position where iron formation should occur, there are rocks that exhibit textures reminiscent of nodular and mosaic sulphates.

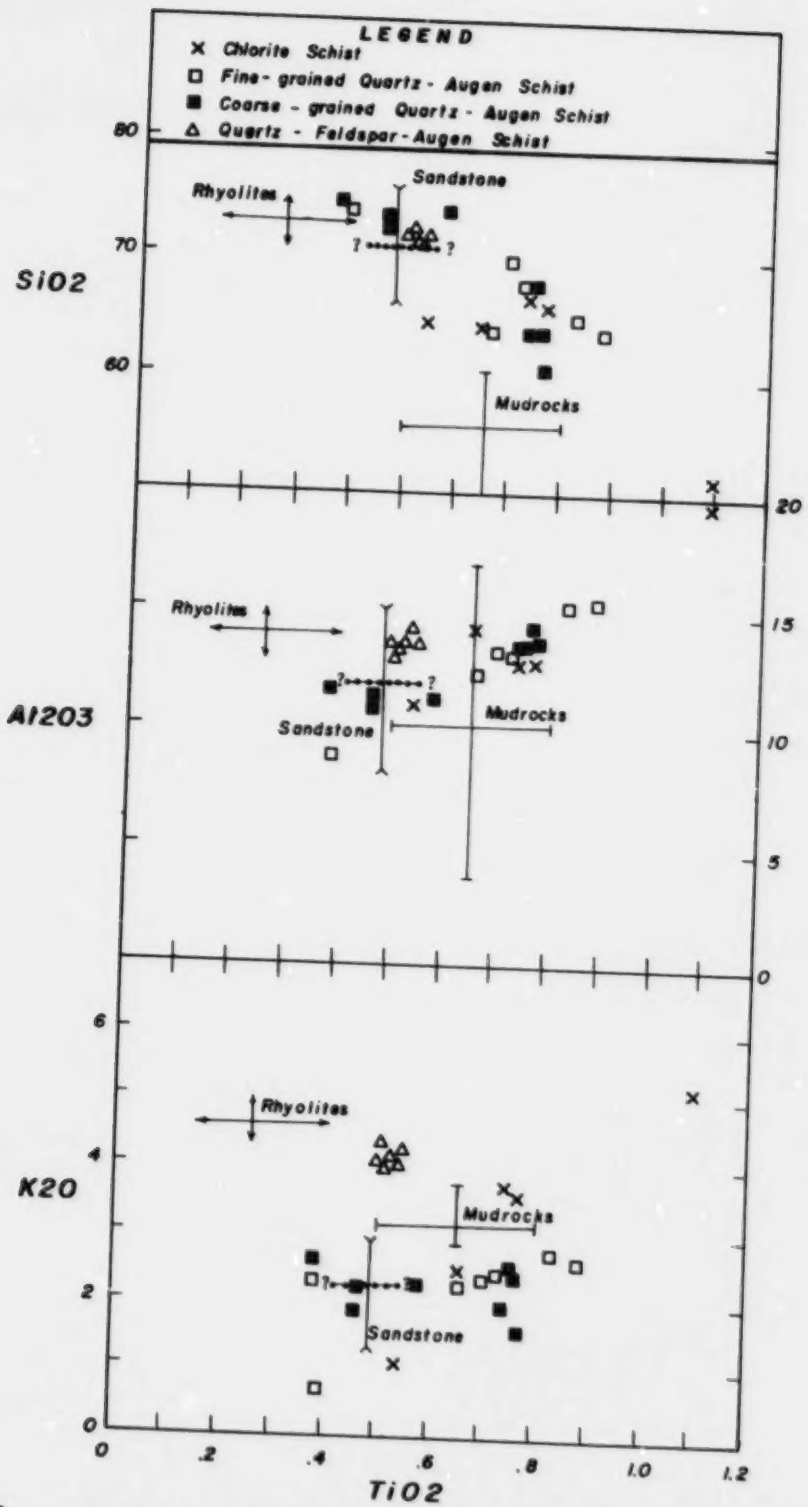


FIGURE 18. Two-element variation diagrams showing $SiO_2$, $Al_2O_3$, and $K_2O$ plotted against $TiO_2$. The compositional ranges of rhyolites, sandstones, and mudstones from Table 3 are included.

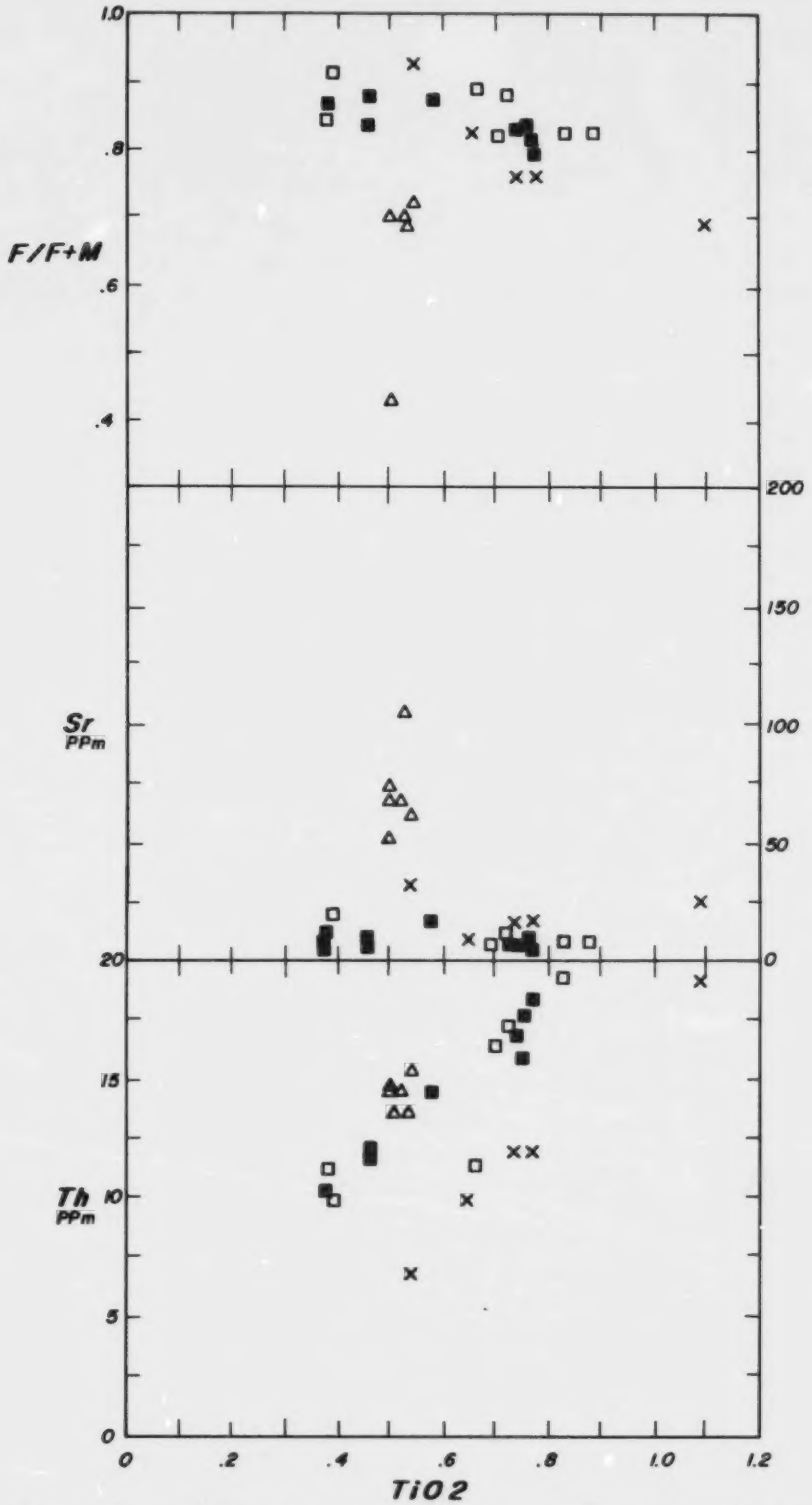


FIGURE 19. Two-element variation diagrams showing F/F+M, Sr, and Th plotted against $TiO_2$. Symbols as in Figure 18.

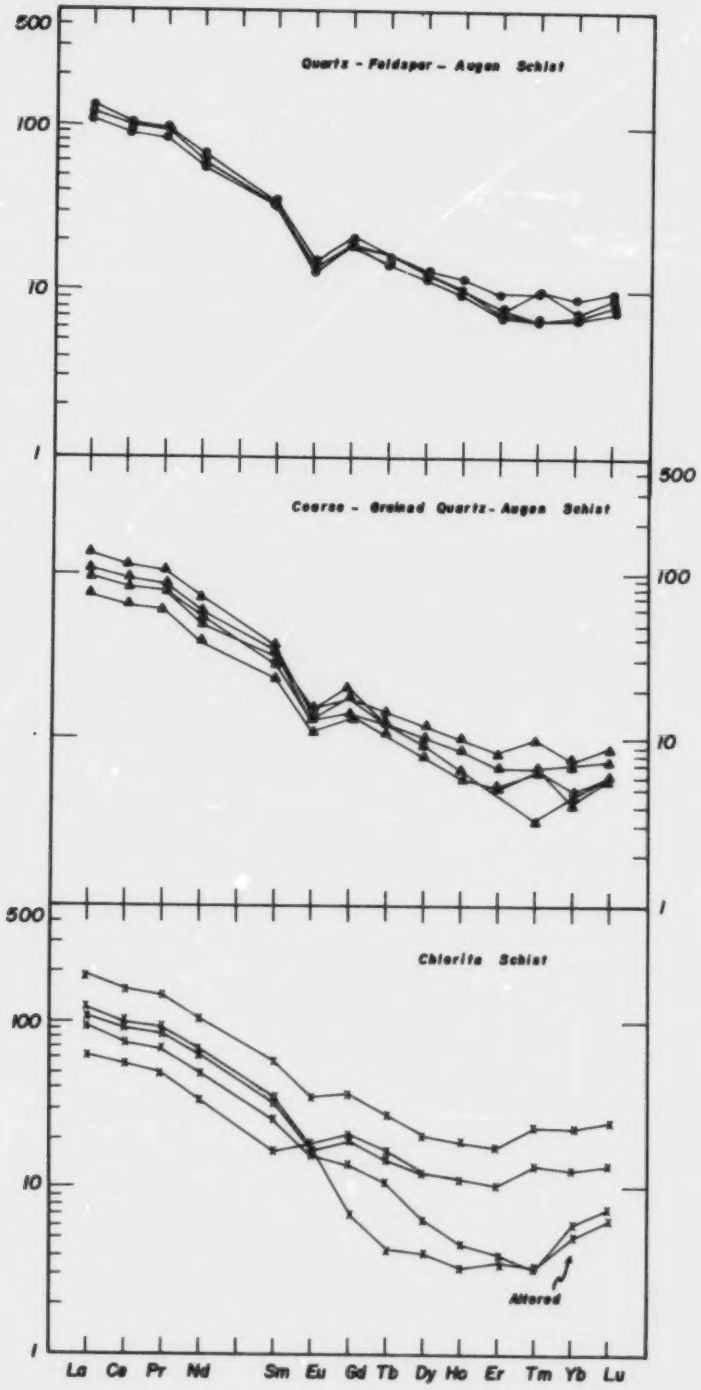


FIGURE 20. REE profiles for QFAS (top), QAS (middle), and CS (bottom). REE normalization factors are from Nakamura (1974).

Possible swallow-tail gypsum pseudomorphs have also been observed.

5) Felsic volcanic rocks are abundant in the post-ore sequence at Brunswick No. 6 and are mainly aphyric or feldspar-porphyritic rhyolites and their auto-brecciated equivalents (hyaloclastites). The idealized depositional facies of a subaqueous rhyolite are depicted in Figure 21.
6) The difference in post-ore stratigraphy from No. 12 to No. 6 indicates that rhyolites are laterally equivalent to sedimentary rocks.

If the stratigraphic relationships in the vicinity of the Brunswick deposits can be extrapolated to the rest of the Bathurst camp, then a diagrammatic depositional model can be constructed (Figure 22). In the model, a felsic volcanic pile, largely composed of subaqueous rhyolite domes and hyaloclastites, interfingers with coeval sedimentary rocks. The lower part of the pile consists of quartz-feldspar porphyritic (2-15 mm) lavas and erosional detritus derived from these lavas (or unidentified granites). The upper part consists of aphyric or sparsely feldspar-porphyritic (generally less than 3 mm) lavas and their associated hyaloclastites. The longevity of the volcanism is uncertain, but is restricted to a 10 m.y. interval (Llandeilian or late Middle Ordovician) based upon fossils and radiometric ages (van Staal and Fyffe, in press).

The lateral and vertical distribution of sulphide deposits with respect to the volcanic pile, and the relationship between volcanism and sulphide genesis are not well established. However, the following four observations put constraints on genetic models illustrated in Figure 23:

1) The immediate footwall rocks to the deposits are mudstones rather than volcanic rocks.
2) Hydrothermal breccias are absent in the footwall, although alteration (feeder) pipes have been identified in places.
3) The deposits mainly contain Zn+Pb$\pm$Cu and their lateral extent is generally much greater than their thickness.
4) Some deposits are capped by oxide-facies iron formation; others are not.

Based on the above observations and the results from the pilot lithogeochemical study, the following inferences can be made regarding a genetic model or models:

1) Caldera complexes are unlikely to exist in the Bathurst Camp if true pyroclastic rocks are rare or absent. The eruption volumes of rhyolitic lavas are too small to affect catastrophic subsidence, i.e., caldera collapse. The original distribution of rhyolite domes must have been controlled by pre-existing fracture zones.

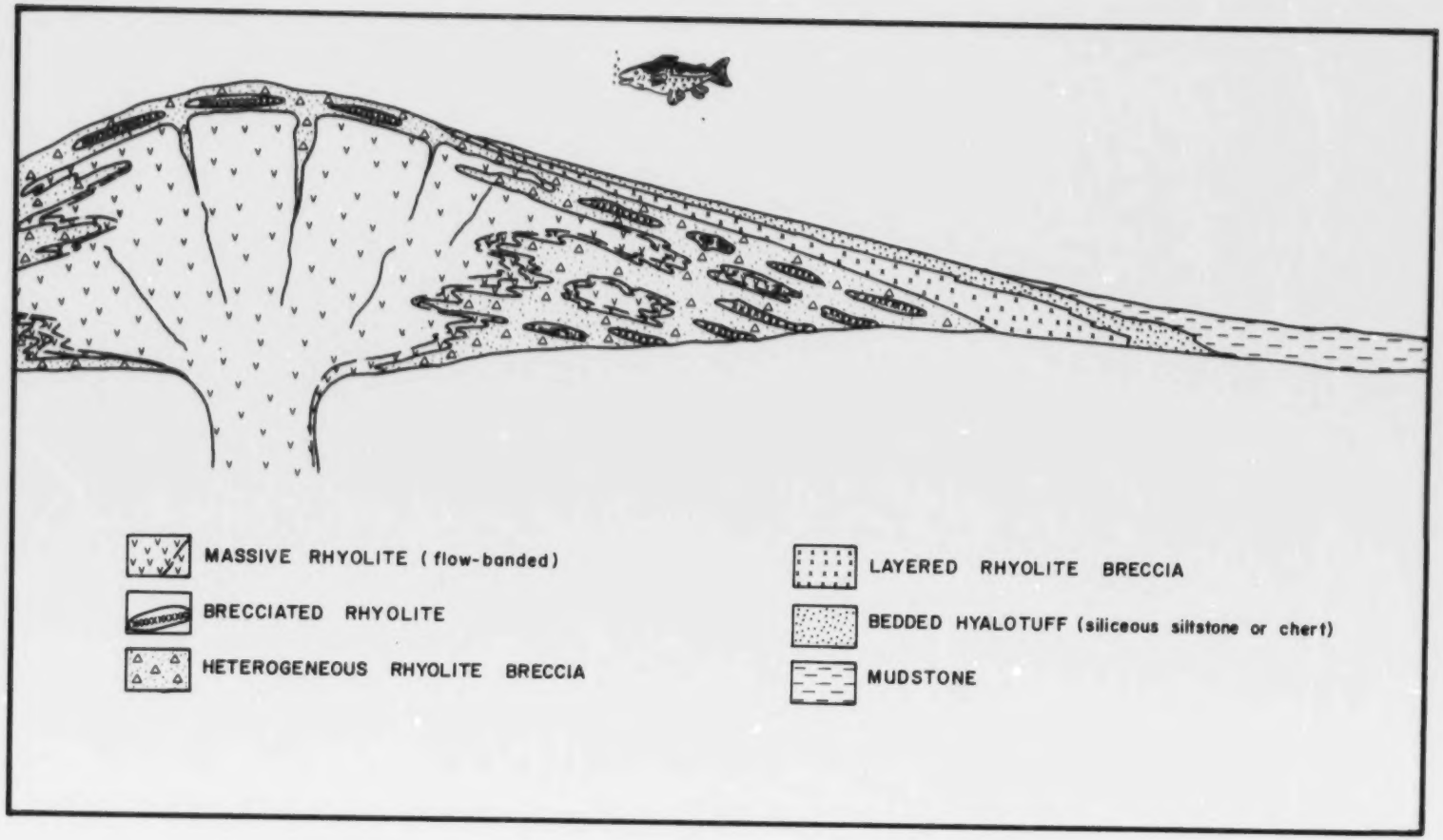


FIGURE 21. Diagrammatic depositional facies of a subaqueous rhyolite flow (modified after DeRosen-Spence et al. 1980 and Pichler 1965).

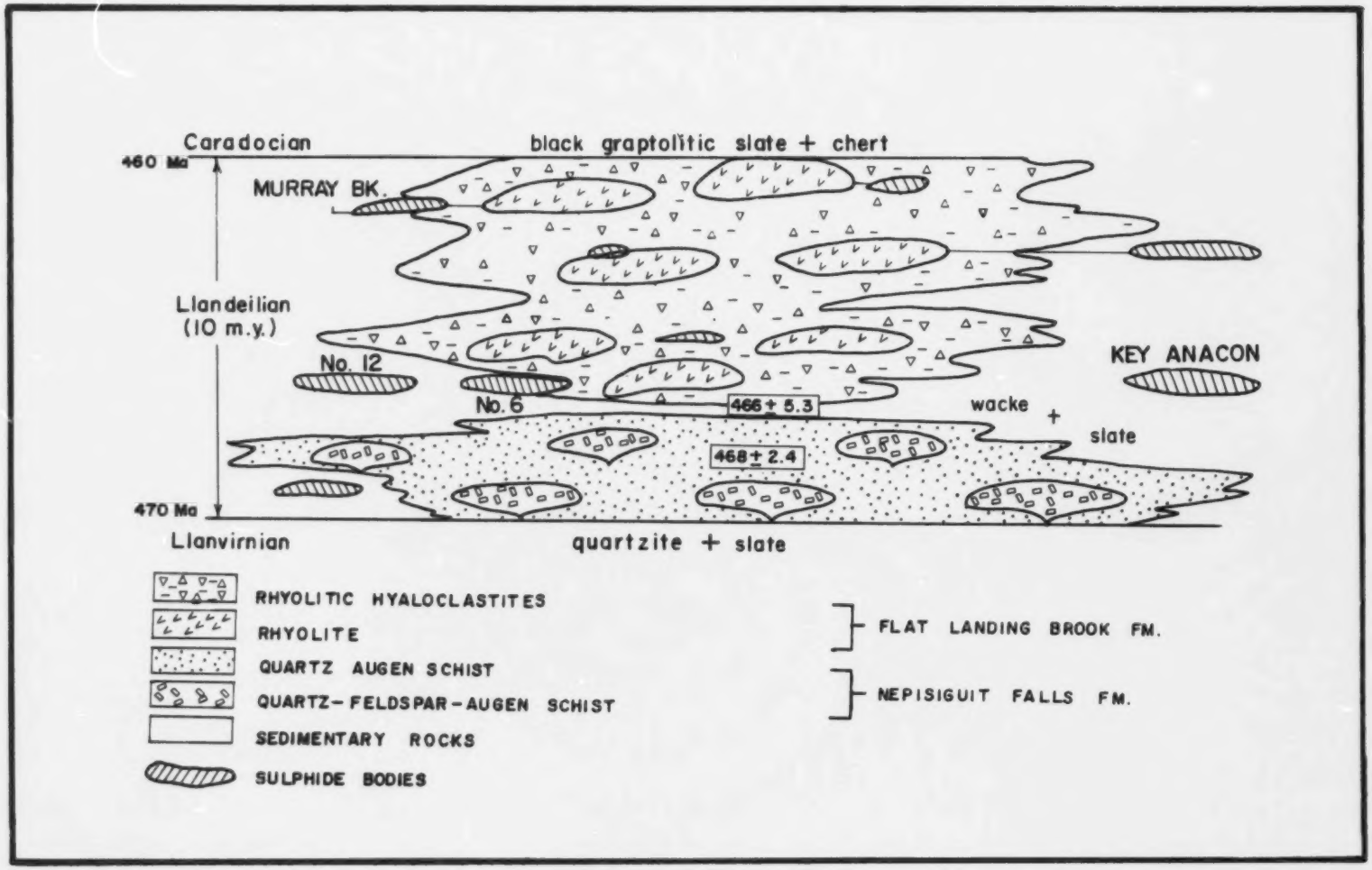


FIGURE 22. Diagrammatic representation of the stratigraphy of the felsic volcanic pile. Formation names and isotopic ages are from van Staal and Fyffe (in press).

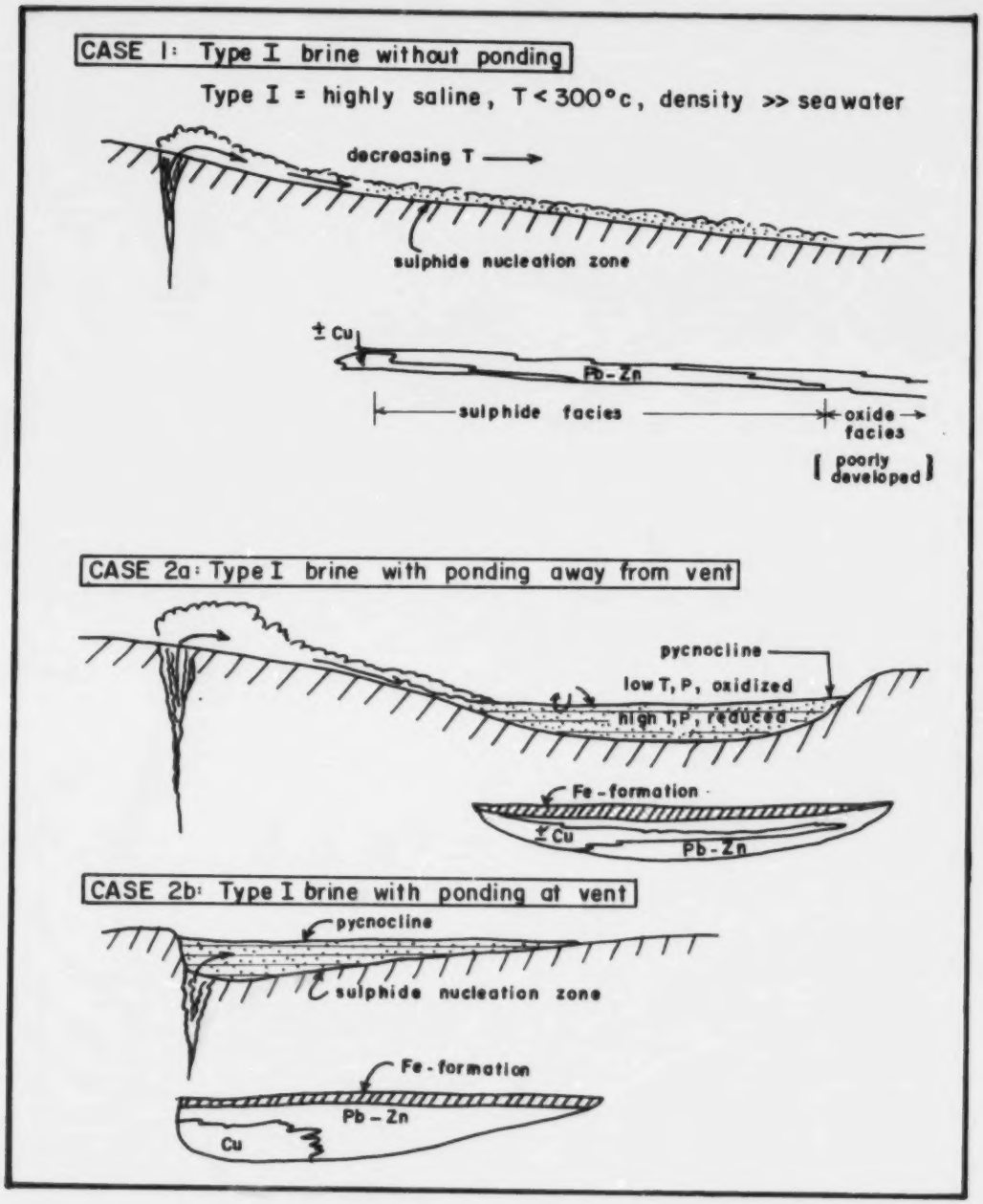


FIGURE 23. Hypothetical models showing three scenarios of sulphide deposition from a high-density brine (modified after Lydon 1988).

2) The deposits are stratiform bodies within mudstones requiring that they are distal if the sulphide-bearing fluids are derived from rhyolite domes, or that they are of undetermined proximity if the fluids were magmatically heated but not directly associated with a rhyolite dome.
3) The sulphide-bearing fluids could have had both metamorphic and magmatic components. The Pb content in the deposits does not favour a significant magmatic component because Pb generally behaves as a compatible element during differentiation of felsic magmas, i.e., lead is not concentrated appreciably in the melt. The absence of hydrothermal breccias in the footwall rocks also favours a non-magmatic fluid under enough confining pressure to prevent phreatic explosion, probably more than 1000 m of water (cf. Lydon 1988).
4) The presence of fine-grained sedimentary host rocks and the absence of hydrothermal breccias suggest that the sulphides were deposited from a high-density (saline), relatively low-temperature (less than 300°C) fluid (Type I solution of Sato 1972). Such a brine, if unponded, would form a deposit with a distal iron formation (case 1 in Figure 23), but if ponded, would form a deposit with a capping iron formation (cases 2a and 2b in Figure 23). Furthermore, a deposit without a capping iron formation should not have a footwall alteration pipe.

Finally, we emphasize that the preceding inferences are far from demonstrated facts. They are presented to stimulate thought and precipitate a search for answers to the fundamental questions concerning the nature and genesis of the sulphide deposits in the Bathurst Camp.

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**GEOLOGICAL SURVEYS BRANCH**

**SUSSEX REGIONAL OFFICE**

# ACTIVITIES OF THE SUSSEX REGIONAL OFFICE

A.A. Ruitenberg, Regional Geologist

The Sussex Regional Office is staffed by A.A. Ruitenberg (Regional Geologist), M.J. McLeod (Assistant Regional Geologist), J.M. Mazerolle (Engineering Technician and Claims Inspector), and F.H. Kelly (Administrative Services Officer). S.E. Watters, D.G. Rose, and S.R. Johnson were employed under the Canada-New Brunswick MDA. A.D. Roy, S. McDonald, and J. Todd were hired as field staff for the summer and fall field seasons.

M.J. McLeod, S.C. Johnson, and A.A. Ruitenberg compiled the regional geology of and field checked problem areas in the western part of 21 H as part of a regional, 1:250 000 scale compilation of southern New Brunswick.

A.D. Roy and J. Todd commenced a detailed mapping program of the Lake George Antimony-Gold Deposit. Most of the work was conducted in the structurally complex, western part of the vein system.

D.G. Rose and S. McDonald located and described the major mineral occurrences in the area covered by 1:250 000 map sheet 21 H and parts of 21 I/3 and 21 G/1.

M.J. McLeod completed a set of 1:20 000-scale maps of the Saint George Batholith area. These maps have been compiled at a 1:50 000 scale and will accompany a report on the geology, geochemistry, and mineral deposits of the batholith to be published as a memoir. S.E. Watters completed a detailed report on the structure and alteration associated with the Hercynian gold deposits in the Cape Spencer area. D.G. Rose and S.C. Johnson completed a report describing the Provincial computerized mineral occurrence file. A.A. Ruitenberg, S.C. Johnson, and L.R. Fyffe completed a paper on gold deposits in New Brunswick, which was submitted for publication to the Canadian Mining and Metallurgical Bulletin. A report by A.A. Ruitenberg and L.R. Fyffe on granite-related mineral deposits in New Brunswick was updated.

F.H. Kelly and M.J. Mazerolle continued to provide their effective support services to the geological staff and to the mineral industry.

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Le Bureau Régional de Sussex compte comme effectifs A.A. Ruitenberg (Géologue Régional), M.J. McLeod (Géologue Régional Assistant), J.M. Mazerolle (Technicien d'Ingénierie et Inspecteur de Claims), et F.H. Kelly (Officière de Services Administrative). S.E. Watters, D.G. Rose, et S.R. Johnson ont été employés sous l'EDM Canada-Nouveau-Brunswick. A.D. Roy, S. McDonald, et J. Todd ont été engagés comme éffectifs de terrain pour les périodes d'été et d'autôme.

M.J. McLeod, S.C. Johnson, et A.A. Ruitenberg ont compilé la géologie régionale, et vérifié les sites avec problèmes, dans la parties occidental de 21 H comme faisant part d'une compilation régionale à l'échelle 1:250 000 du sud du Nouveau-Brunswick.

A.D. Roy et J. Todd a commencé un programme de cartographie détaillée du dépôt d'antimoine/or du lac George. La plus grande partie du travail a déroulé dans la partie occidentale, à structure compliquée, du systême à veines.

D.G. Rose et S. McDonald ont localisé et décrits les sites majeurs de minéralisation dans les régions surs les feuilles de carte, a 1:250 000, 21 H, et en des parties de 21 I/3 et 21 G/1.

M.J. McLeod a terminé une suite de cartes a l'échelle 1:20 000 de la région du batholite de St. George. Ces cartes ont été compilées a l'échelle 1:50 000 et accompagneront un rapport sur le géologie, géochimie, et gites du batholite, à être publié sous forme d'une mémoire. S.E. Watters a terminé un rapport de détail sur la structure et l'altération associées avec les gites d'or d'âge Hercynien de la région du Cap Spencer. D.G. Rose et S.G. Johnson ont terminé un rapport qui décrit le classement par ordinateur des gites à mineraux. A.A. Ruitenberg, S.C. Johnson, et L.R. Fyffe ont terminé un papier sur les gites d'or au Nouveau Brunswick, lequel on a soumis pour publication au "Canadian Mining and Metallurgical Bulletin". Un rapport par A.A. Ruitenberg et L.R. Fyffe sur les gites en association avec les granites au Nouveau Brunswick a été mis à jour.

F.H. Kelly et M.J. Mazerolle ont continué à donner leur support effectif de services aux cadres géologiques et à l'industrie minière.

The Sussex Regional Office is staffed by Arie Ruitenberg (Regional Geologist), Malcolm McLeod (Assistant Regional Geologist), Maurice Mazerolle (Engineering Technician and Claims Inspector), and Freda Kelly (Administrative Services Officer). Sheila Watters, David Rose, and Susan Johnson were employed under the Canada - New Brunswick MDA. Angela Roy, Sean McDonald, and Jody Todd were hired as field staff for the summer and fall field seasons. We regret the sudden death of Dennis Hanley in October, 1989. Dennis was an active forest ranger with an intensive interest in soils and geology and worked for us in Charlotte County during the summer of 1988.

**PROGRAMS AND PROJECTS**

M.J. McLeod, S.C. Johnson, and A.A. Ruitenberg compiled the regional geology of and field checked problem areas in the western part of 21 H as part of a regional, 1:250 000 scale compilation of southern New Brunswick. The main emphasis in the field checking was on regional correlation and defining major fault systems, which controlled the emplacement of epigenetic mineral deposits. Several new mineral occurrences were found along these structures. This work will be continued in 1990 and the results will be published on colored 1:250 000 maps.

A.D. Roy and J. Todd commenced a detailed mapping program of the Lake George Antimony-Gold Deposit. Most of the work was conducted in the structurally complex, western part of the vein system. The objective of the investigation is to delineate the structures that controlled emplacement of the antimony and gold ores, which will assist in exploration for other deposits.

D.G. Rose and S. McDonald located and described the major mineral occurrences in the area covered by 1:250 000 map sheet 21 H and parts of 21 I/3 and 21 G/1. Samples were cut with a diamond saw and representative material was sent for assay. The results of this work will be used to update the computerized mineral occurrence file.

M.J. McLeod made the final corrections on the 1:20 000-scale maps of the Saint George Batholith and a memoir on the geology, geochemistry, and mineral deposits of the batholith was completed. S.E. Watters completed a detailed report on the structure and alteration associated with the Hercynian gold deposits in the Cape Spencer area. D.G. Rose and S.C. Johnson completed a report describing the provincial computerized mineral deposits file. A.A. Ruitenberg, S.C. Johnson, and L.R. Fyffe completed a paper on the gold deposits in New Brunswick, which was submitted for publication to the Canadian Mining and Metallurgical Bulletin. A report by A.A. Ruitenberg and L.R. Fyffe on granite-related mineral deposits in New Brunswick was updated.

The regional geologist participated in a committee charged with evaluating Mineral Exploration Program (MESP) proposals. He also was appointed a member and made several submissions to the resource sub-committee of the Saint Croix International Waterway Committee, which was established between the State of Maine and the Province of New Brunswick.

F.H. Kelly and J.M. Mazerolle continued to provide their effective support services to the geological staff and to the mineral industry.

J.M. Mazerolle completed drafting the 1:20 000 scale geological maps of the Saint George Batholith (M.J. McLeod) and detailed maps, sections and diagrams of the Cape Spencer area (S.E. Watters). A set of 1:50 000 scale Assessment Report Maps of Southern New Brunswick was compiled. A set of ten map sheets at a scale of 1:250 000 showing the locations of mineral occurrences included in the computerized mineral occurrence file for New Brunswick was drafted. Computerization of Assessment Reports, including mineralized drill core intersections, was continued. Various claim inspections were made in the field. Assistance was also provided in field examination of mineral occurrences.

In addition to her regular duties, the administrative services officer, F.H. Kelly, prepared a computerized inventory of all geological maps stored in the Sussex Regional Office. This inventory will be kept up to date to facilitate services to the mineral industry.

# GOLD-BEARING ROCKS - BAY OF FUNDY COASTAL ZONE SAINT JOHN COUNTY, NEW BRUNSWICK (MDA)

S.E. Watters, Project Geologist

Work in the final year of the MDA project on the gold-bearing rocks of the Fundy Coastal Zone was concentrated on the immediate area of the gold deposits at Cape Spencer. The deposits occur within a major Hercynian fold and thrust belt that extends along the Fundy Coastal Zone of New Brunswick. Rock units in the Cape Spencer area consist of Precambrian granitoid and volcanic rocks as well as three sedimentary formations, two of Carboniferous age and one Carboniferous or older all of which are juxtaposed by Hercynian faulting.

Effects of the Hercynian deformation include regional-scale northeast-trending recumbent folds ($D_1$) accompanied by a penetrative axial-planar cleavage ($S_1$). A second phase ($D_2$) produced northwest- and southeast-dipping thrust faults with associated northeast-trending overturned folds accompanied by a spaced axial-planar cleavage ($S_2$).

The $D_2$ phase thrust faults and folds localize illitic alteration (illite, ankerite, leucoxene +/- pyrite +/- quartz) and associated quartz-ankerite and quartz-chalcopyrite veins. The gold deposits occur both in mylonitized granitoid rocks and in sedimentary rocks of the Cape Spencer Formation, within pyrite-rich, intensely illitized zones controlled by $D_2$ structures. Ore grades in the granitoids are generally restricted to zones with abundant early ($D_1$?) specularite veins. Gold occurs as microscopic grains generally enclosed by or marginal to pyrite grains. It occurs both in the illitized host rock and in the related veins. Minor associated sulphides include chalcopyrite plus minor sphalerite, galena, and other copper sulphides.

Early ($D_1$ and/or pre-$D_1$) extensive propylitic alteration of the Precambrian units involved addition of Na, $CO_2$, possible addition of $H_2O+$, removal of K and probable removal of Fe. The overprinting illitic alteration involved addition of K, Ba, and $CO_2$ and removal of Si and Na. Local albitic alteration overprints illitically altered rocks, resulting in addition of Na and removal of K, Rb, and Ba.

Sulphur isotopic analyses of ore pyrites indicate a similar sulphur source to that of the Meguma gold deposits in Nova Scotia, a possible source reservoir being rocks of the Meguma Group. Oxygen isotopic analyses of quartz-chlorite pairs from veins within the illitized rocks of the ore zones yield probable temperatures of 220 to 240°C. These veins predate illitic alteration and gold deposition.

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Le travail pour l'année final sur les roches portant de l'or dans la Zone Cotière Fundy a été concentré sur la région proche des gîtes d'or au Cap Spencer. Les gîtes se trouvent dans un plissement majeur Hercynien à failles couchées qui s'étend le long du Zone Cotière Fundy du Nouveau-Brunswick. Des unités de roches dans la région du Cap Spencer sont de roches pré-Cambriennes granitiques et volcaniques, et aussi trois formations sédimentaires, deux d'âge Carbonifère et une Carbonifère ou plus veille, toutes juxtaposées par des failles Hercyniennes.

Les effets de la déformation Hercynienne comprennent des plis ($D_1$) régionaux couchés, à orientation nord-est, accompagnés par un clivage ($S_1$) de pénétration axiale et plane. Une deuxième phase ($D_2$) a produit des failles d'enchevêtrement à pendage nord-ouest et sud-est avec une association à plis renversé d'orientation nord-est et accompagnés du clivage ($S_2$) axial, plan et espacé.

Les failles d'enchevêtrement et plis de la phase ($D_2$) localisent une altération à illite (illite, ankérite, leucoxène, +/- pyrite, +/- quartz) et des veines associées de quartz/ankérite et quartz/chalcopyrite. Les gites d'or se trouvent et dans les roches granitoides et mylonitiques et les roches sédimentaires de la Formation Cap Spencer, au sein de zones riches en pyrite et très riches en illite, et sous le control de structures de la phase $D_2$. Les teneurs qui pourraient être du minerai sont restreintes de façon générale aux zones portant une abondance de veines précoces ($D_1$?) de specularite. L'or se trouve en grains microscopiques, de façon génerale à l'intérieur ou à côté de grains de pyrite, et ceci dans la roche à illite et les veines accompagnantes. Les sulphures mineurs accompagnants comprennent la chalcopyrite et très peu de sphalerite, galène, et d'autres sulfures à cuivre.

Une altération initiale ($D_1$ et/ou pré-$D_1$) étendue, à propylite, des unités pre-Cambriennes a impliqué l'apport de Na, $CO_2$, et possiblement $H_2O(+)$, et l'enlèvement de K et probablement de Fe. L'altération en illite qui a suivi a impliqué l'addition de K, Ba, et $CO_2$ et la soustraction de Si et Na. Une altération locale par l'albite a suivi dans les roches à illite, résultant dans l'apport de Na et l'enlevement de K, Rb, et Ba.

Les analyses isotopiques du sulfur des pyrites du minerai indiquent une source semblable pour le sulfur à celle des gites d'or en Nouvelle Ecosse, une source possible étant les roches mêmes du Groupe Meguma. Les analyses isotopiques de l'oxygène des paires quartz/chlorite des veines provenant des roches à illite dans les zones à minerai donnent des températures probables de 220 à 240°C. Ces veines sont antérieures à l'altération en illite et la déposition de l'or.

The final year of the MDA project on the gold-bearing rocks of the Fundy coastal zone was concentrated on the immediate area of the gold deposits at Cape Spencer. Work included detailed interpretation of drill-hole cross-sections with supporting field work, petrographic studies, completion of geochemical interpretation, additional isotopic analyses, and preparation of the final report.

The gold deposits at Cape Spencer occur within a major Hercynian fold and thrust belt that extends along the Fundy Coastal Zone of New Brunswick. Details of the surface geology in the immediate area of the Gordex Minerals and Mispec Resources deposits at Cape Spencer are given in Figure 24. Regional geology of the Cape Spencer area and descriptions of the three sedimentary formations and the Precambrian granitoid and volcanic rocks are given by Ruitenberg (1984) and Watters (1985, 1986, 1987, 1988a, 1988b).

Effects of two major deformations have been observed in all the rock units. The first phase ($D_1$) produced regional scale northeast-trending overturned folds ($F_1$) and a gently southeast-dipping penetrative cleavage ($S_1$) that is axial planar to the regional folds. $S_1$-parallel specularite veins, inferred to be syn-$D_1$, are locally abundant and formed in both the Precambrian units and the Cape Spencer Formation. The second deformation ($D_2$) produced conjugate northwest- and southeast-dipping thrust faults along with associated northeast-

trending, southeast- and northwest-closing recumbent folds ($F_2$). A spaced cleavage ($S_2$) is axial planar to these folds and dips northwest, southeast, and locally southwest. Effects of an earlier deformation of the Precambrian units (pre-$D_1$) are largely obliterated by the intense Hercynian deformation. Shearing and mylonitization were products of this early event.

The earliest identifiable rock alterations are widespread propylitic and local illitic zones in the Precambrian units. At least some of this alteration predated deposition of the Cape Spencer Formation. Later, zones of illitic alteration (illite, ankerite, leucoxene +/- pyrite +/- quartz) formed in both the Precambrian units and the sedimentary formations, controlled by $D_2$ thrust faults and folds. More restricted albitic alteration (albite, quartz, ankerite +/- illite +/- pyrite) locally overprints illitized rock. Associated with the illitic alteration are sets of veins dominated variably by quartz and ankerite +/- pyrite and by quartz and chalcopyrite +/- ankerite +/- pyrite. The quartz-ankerite veins mainly follow the folded $S_1$ cleavage and the $S_2$ cleavage. Some also cut steeply across the $F_2$ fold axes. The quartz-chalcopyrite veins occur mainly within $D_2$-thrust faults that are subparallel to the $S_2$ cleavage and in the steeper structures that are more or less perpendicular to the $F_2$ fold axes.

Representative cross-sections of the two gold deposits, the Gordex Minerals (West Ore Zone - East Ore Zone) deposit and the Mispec Resources (Road Zone - Birches Zone) deposit are given in Figure 25. The deposits are located within pyrite-rich, intensely illitized zones controlled by $D_2$ structures. Ore is hosted both by the sedimentary rocks of the Cape Spencer Formation and by mylonitized granitoid. Ore grades in the latter appear to be restricted, in general, to zones containing an abundance of early specularite veins.

The West Ore Zone of the Gordex deposit (Figures 24 and 25) is located in an $S_2$-parallel zone of pyrite-rich, intensely sheared and illitized sedimentary and granitoid rocks on the northwest flank of the Precambrian granitoid body. The overall orientation of the units and of the zone of illitic alteration is also sub-parallel with the $S_2$ foliation.

The East Ore Zone occurs in similar units over the southeast-dipping buried flank of the granitoid body and is separated from it by a section of unaltered sedimentary rocks. It is bounded to the north by a late normal, moderately south-southeast-dipping fault. The East Ore Zone is interpreted to be the down-faulted extension of the West Ore Zone.

The Road Zone of Mispec Resources (Figures 24 and 25) occurs in an $S_2$-parallel zone of pyrite-rich, illitized and faulted sedimentary rocks lying over the northwest-dipping

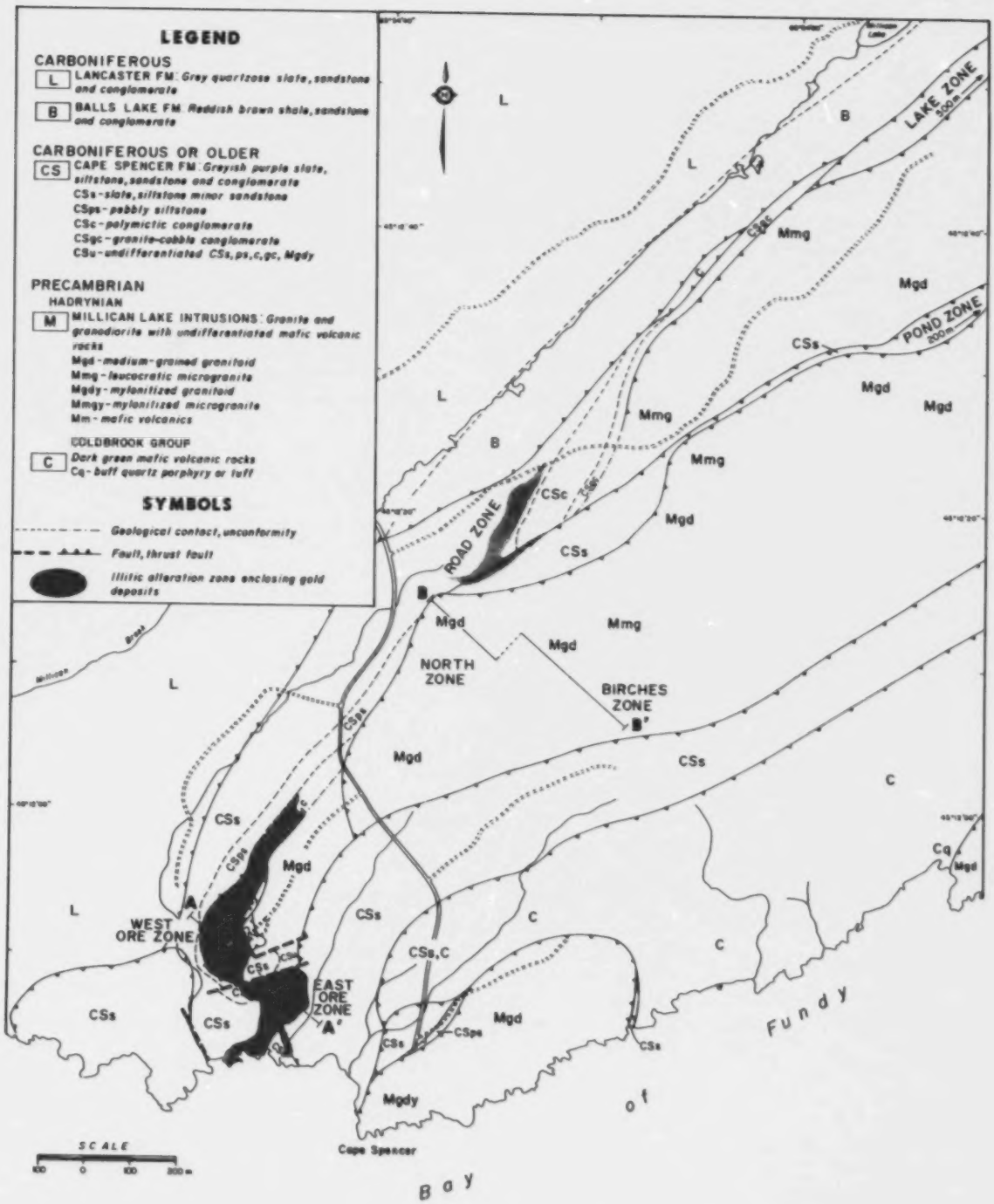
LEGEND
CARBONIFEROUS
L LANCASTER FM: Grey quartzose slate, sandstone and conglomerate
B BALLS LAKE FM: Reddish brown shale, sandstone and conglomerate
CARBONIFEROUS OR OLDER
CS CAPE SPENCER FM: Greyish purple slate, siltstone, sandstone and conglomerate
CSs - slate, siltstone minor sandstone
CSps - pebbly siltstone
CSc - polymictic conglomerate
CSgc - granite-cobble conglomerate
CSu - undifferentiated CSs, ps, c, gc, Mgdy
PRECAMBRIAN
HADRYNIAN
M MILLICAN LAKE INTRUSIONS: Granite and granodiorite with undifferentiated mafic volcanic rocks
Mgd - medium-grained granitoid
Mmg - leucocratic microgranite
Mgdy - mylonitized granitoid
Mmgy - mylonitized microgranite
Mm - mafic volcanics
COLDBROOK GROUP
C Dark green mafic volcanic rocks
Cq - buff quartz porphyry or tuff
SYMBOLS
Geological contact, unconformity
Fault, thrust fault
Illitic alteration zone enclosing gold deposits
LAKE ZONE
POND ZONE
ROAD ZONE
NORTH ZONE
BIRCHES ZONE
WEST ORE ZONE
EAST ORE ZONE
Cape Spencer
Bay of Fundy
SCALE

FIGURE 24. Geology in the immediate area of the Gordex Minerals (West Ore Zone - East Ore Zone) deposit and the Mispec Resources (Road Zone - Birches Zone) deposit at Cape Spencer.

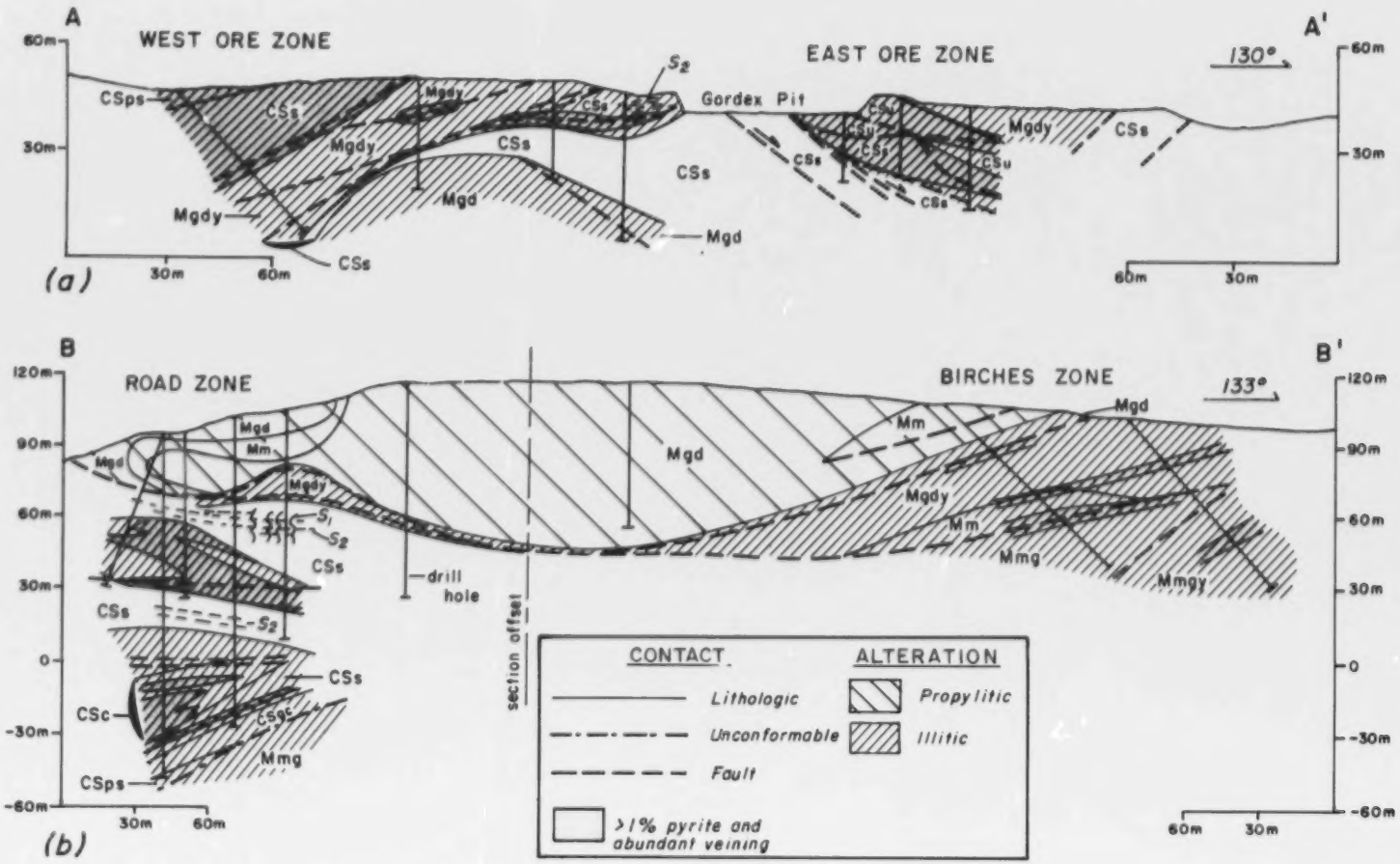


FIGURE 25. Cross-sections A-A′ (West Ore Zone to East Ore Zone) and B-B′ (Road Zone to Birches Zone) in the Cape Spencer area. Location of section lines and legend are provided on Figure 24.

flank of the Precambrian granitoid. It is exposed by erosion at its north end and plunges to the south-southwest, becoming a blind deposit beneath a $D_2$ thrust sheet of granitoid rock. The blind portion of the Road Zone ores extends to the south into the North Zone of Gordex Minerals Ltd.

Petrographic study of the gold ores indicates that gold generally occurs as .005-.1 mm grains and is associated most commonly with pyrite. Here it is enclosed by pyrite, occurs along fractures in pyrite or along its outer margins. Gold is also found in gangue minerals of both the host rock and the veins (within ankerite, quartz, and illite). Gold is commonly concentrated in the folded $S_1$-parallel specularite veins where pyrite occurs in haloes adjacent to crosscutting quartz-ankerite veins. A variety of opaque minerals are commonly associated with the gold including sphalerite, galena, chalcopyrite, bornite, digenite, and covellite. All of these except chalcopyrite occur in very minor amounts in the ores and are rarely identifiable megascopically. Microfabrics indicate that most or all of the gold was deposited during the $D_2$ phase of deformation.

Geochemical analyses of propylitized, illitized and albitized rocks and their unaltered equivalents were done to assess chemical changes associated with the alterations. Results were interpreted with the aid of isocon diagrams (Grant 1986) and supported by petrographic observations. The following chemical changes were inferred:

1. Propylitic alteration of the granitoid rocks involved addition of Na, $CO_2$, probable addition of $H_2O^+$, removal of K and probable removal of Fe.
2. Illitic alteration of granitoid, microgranitic, mafic volcanic, and sedimentary rocks involved addition of K, Ba, $CO_2$, probable addition of sulphur (S), and removal of Si and Na.
3. Illitic alteration of the Millican Lake Intrusions involved the removal of Fe, Mg, P, Cu, Pb, Zn, V, Cr, and Co from the enclosed mafic volcanic rocks and addition of most of these elements (except Cu, Pb, and Cr) to the granitoid rocks.
4. Illitic alteration involved local introduction of Au, Be, B, F, Rb, Y, W, Tl, U, Eu, and Lu and local removal of As and Li.
5. Albitic alteration of microgranitic, granitoid, mafic volcanic and sedimentary rocks involved addition of Na and depletion of K, Rb, and Ba.
6. Analyses of quartz-chalcopyrite veins shows local concentrations of Cu, Au, Ag, As, Sb, Te, and S.

Isotopic analyses included both sulphur and oxygen isotopes for the determination of sulphur source and temperatures respectively. Additional analyses of sulphur isotopes from pyrites were done to corroborate results of earlier analyses

from the propylitized, illitized and albitized rocks. The total range of $\delta^{34}S_{CDT}$ values in the pyrites of 50 samples (n=50) from all three alteration types, including samples from various rock types and from veins, is 0.4 to 14.7 per mille. The total range of values from the various chloritized host rocks is 1.6 to 9.4 per mille (n=5) and the range from various illitized host rocks (n=20) is 5.0-14.7 per mille (on average 5 per mille higher in the illitized rock). Isotopic ratios in pyrites from quartz-ankerite veins tend to mirror the ratios in pyrites from the adjacent illitized host rock. The total range from these veins is 5.1-14.4 per mille (n=6). $\delta^{34}S$ values from albitized rocks, where albitic alteration overprints illitically altered mafic and granitoid rocks are 9.7 to 13.3 per mille (n=7). This is similar to the range in illitized rocks. Pyrites from quartz-chalcopyrite veins yielded the lowest range of $\delta^{34}S$ values (0.4-5.8 per mille) (n=4). Based on mineral relationships and on the narrow range of $\delta^{34}S$ values from the illitized rocks at Cape Spencer it is inferred that fluids had low oxygen fugacity and that $\delta^{34}S$ of the pyrite is a good approximation of $\delta^{34}S$ of the ore-fluid (Ohmoto and Rye 1979). A high water-rock ratio is also indicated.

The total range of $\delta^{34}S$ values from illitized rocks at Cape Spencer falls mostly within the range reported by Kontak et al. (1988) from sulphides of various gold deposits hosted by the early Paleozoic Meguma Group in Nova Scotia. The range of $\delta^{34}S$ values also falls between the $\delta^{34}S$ values of greywackes and slates of the Meguma Group (Kontak et al. 1988). This suggests a similar source of sulphur for both the Cape Spencer and the Meguma gold deposits, possibly from the Meguma Terrain. Although a unique source reservoir of sulphur cannot be defined, the $\delta^{34}S$ values of the illitized rocks at Cape Spencer are unlikely to have been produced by sulphur derived from dominantly magmatic fluids (Ohmoto and Rye 1979).

Both sulphur and oxygen isotope analyses were performed on mineral pairs for possible temperature determination. Results of analyses from four pyrite-chalcopyrite pairs from quartz-chalcopyrite veins were too erratic for temperature determination. Three vein samples containing intergrown quartz and chlorite were taken from illitic alteration zones of both the East and West Ore Zones of the Gordex deposit. Oxygen isotope analyses on the three quartz-chlorite pairs indicate a total possible temperature range of 210-240°C (Longstaff, written communication). The most reliable pairs indicate a temperature range of 220-240°C. These veins are inferred to predate illitic alteration since the outer margins of some of the chlorite is altered to illite.

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## NEW BRUNSWICK COMPUTERIZED MINERAL OCCURRENCE FILE (MDA)

D.G. Rose and S.C. Johnson, Project Geologists

In the late autumn of 1988 and early 1989, D.G. Rose and S.C. Johnson edited data in the computerized mineral occurrence file to ensure accuracy and consistency. The number of entries in the computer file was increased to 798.

A final report on the project - including methodology, description of the computer file contents, preliminary data analysis and examples of file applications - was completed in March of 1989. When published, the report will be accompanied by a copy of the database on diskettes. A set of 10 map sheets showing the locations of all occurrences on a geographic background, at a scale of 1:250 000, was drafted by M. Mazerolle to supplement the computerized file.

In the summer of 1989, D.G. Rose, with the assistance of S. McDonald, began field examination of selected mineral occurrences. This aspect of the project includes locating the most significant occurrences, sampling them and updating the descriptions as required. The area completed by early September is covered by map sheet 21 H. A portion of 21 I/3 was examined (Salem area) and work was continuing in map sheet 21 G. By early September, 57 occurrences had been targeted for examination and 53 of these were located in the field. In addition, 15 other occurrences were discovered and sampled.

Results of the field examination and assays will be incorporated into the database, and made available as computer-generated reports. The samples collected will become part of a collection to accompany the New Brunswick mineral inventory files.

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Tard dans l'automne de 1988 et tôt en 1989, D.G. Rose and S.C. Johnson ont rédigé des données de la filière à ordinateur sur les indices de minéralisation avec le bût de verifier leur verité et compatibilité. Le nombre d'entrées dans la filière a été augmente à 798.

Un rapport final sur le projet - y compris la méthodologie, une déscription du contenu de la filière, une analyse préliminaire des données, et des exemples des applications de la filière, - a été rédigé en mars, 1989. La publication sera accompagnée par une copie de la base à données sur diskettes. Une ensemble de 10 feuilles à cartes indiquant les emplacements de toutes indices, sur un fond géographique, à l'échelle de 1:250 000, a été mise à la carte par M. Mazerolle pour suppléer la filière à ordinateur.

Dans l'été de 1989, D.G. Rose, avec l'aide de S. McDonald, a commencé l'examen sur le terrain des indices choisies. Cette étape du projet comprends la localisation des indices les plus significatives, leur échantillonage et la mise à jour de leur déscriptions comme requis. La superficie couverte tôt en septembre est celle de la feuille à carte 21 H. Une partie de la feuille 21 I/3 a été etudié (region de Salem) et le travail se continuait sur la feuille 21 G. Tôt en septembre, 57 indices ont été confirmés pour l'étude sur le terrain et 53 de celles-ci ont été trouvés sur le terrain. En outre, 15 autres indices ont été découverts et échantillonés.

Les résultats de l'examen sur le terrain et les analyses seront incorporés dans les données de base, et seront disponible comme rapports sur ordinateur. Les échantillons ramassés feront partie d'une collection accompagnant les filières d'inventaire à minéraux du Nouveau-Brunswick.

# COMPILATION AND CORRELATION OF SOUTHERN NEW BRUNSWICK GEOLOGY, CHARLOTTE, QUEENS, AND KINGS COUNTIES

M.J. McLeod, S.C. Johnson, and A.A. Ruitenberg

The 1:250 000 compilation project for southern New Brunswick was initiated by compiling and field checking the following 1:50 000 map sheets in the western part of 21 H: 21 H/4, 21 H/5, 21 H/12, 21 H/13, and 21 H/14. Numerous sources from the voluminous literature published on southern New Brunswick geology were referred to for this phase of the project.

The western part of 21 H is underlain by fault-bounded belts comprised predominantly of Precambrian rocks in the southeast and Silurian rocks in the northwest. These have been referred to as the Avalon and Mascarene terranes, respectively. The latter, however, is now considered part of a younger sequence deposited upon the Avalon Terrane. Both belts are overlain by Carboniferous and/or Triassic sedimentary rocks that were deposited after the belts were juxtaposed by faulting during the waning stages of the Acadian Orogeny and subsequent faulting events.

Gold and/or base-metal occurrences are intimately associated with most major faults throughout the area. Many of these faults or fault zones, particularly along the shore of the Bay of Fundy, and possibly along the northwestern margin of the Silurian belt, reflect the brittle effects of terrane accretion. Those to the south are mainly Hercynian structures associated with accretion of the Meguma Terrane of Nova Scotia with the Avalon Terrane of southern New Brunswick. Those to the northwest are likely Acadian structures associated with the accretion of the Avalon Terrane against Ordovician rocks of the St. Croix Terrane.

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Le projet de compilation à 1:250 000 du sud du Nouveau-Brunswick a eu son début par la compilation et la verification sur le terrain des cartes à 1:50 000 suivantes de la partie occidentale de 21 H: 21 H/4, 21 H/5, 21 H/12, 21 H/13, et 21 H/14. Des sources nombreuses de la publication volumineuse sur la géologie du Nouveau-Brunswick ont été consultées pour cette étape du projet.

La partie occidentale de 21 H comprend de ceintures, limitées par des failles, de roches à prédominance précambrienne du sud-est silurienne au nord-ouest. Celles-ci ont été appelées les terrains d'Avalon et de Mascarene respectivement. Le dernier, néamoins, est pris aujourd'hui comme faisant part d'une séquence plus jeune déposée sur le Terrain d'Avalon. Les deux ceintures sont couvertes par des roches sédimentaires du Carbonifère et/ou du Trias deposées après la juxtaposition des ceintures par des failles vers la fin de l'orogène Acadien et plus tard.

L'or et/ou sites à métaux de base sont associés de près avec la plupart des failles à travers la région. Beaucoup de ces failles ou zones de failles, en particulier le long du rivage de la baie de Fundy, et peut-être le long de la limite nord-ouest de la ceinture Silurienne, indiquent les effets friables de l'accrétion de terrains. Les failles au sud sont surtout des structures d'âge Hercynien associées a l'accrétion du Terrain Meguma de la Nouvelle Ecosse au Terrain Avalon du sud du Nouveau-Brunswick. Celles au nord-ouest sont probablement des structures Acadiennes associees a l'accretion du Terrain Avalon contre des roches Ordoviciennes du Terrain Ste. Croix.

The 1:250 000 compilation project for southern New Brunswick was initiated by compiling and field checking the following 1:50 000 map sheets in the western part of 21 H: 21 H/4, 21 H/5, 21 H/12, 21 H/13, and 21 H/14. Numerous sources from the voluminous literature published on southern New Brunswick geology were referred to for this phase of the project. The main sources utilized to date include regional field mapping programs by Ruitenberg et al. (1979), McCutcheon and Ruitenberg (1987), Barr and White (1988), Currie (1989), and St. Peter (1989a, 1989b), thesis material by Parker (1984), McCutcheon (1981), and Watters (in preparation), other papers such as Anderle et al. (1979), Plint and Van de Poll (1984), Tanoli et al. (1985), and an unpublished compilation of New Brunswick at a scale of 1:500 000 by D. Hattie.

The western part of 21 H is underlain by fault-bounded belts comprised predominantly of Precambrian rocks in the southeast and Silurian rocks in the northwest (Figure 26). These have been referred to as the Avalon and Mascarene terranes respectively by Fyffe and Fricker (1987). The latter, however is now considered part of a younger sequence deposited upon the Avalon Terrane (Ruitenberg et al., in preparation; Fyffe, this volume). Both belts are overlain by Carboniferous (Unit Cs) and/or Triassic (Unit Ts) sedimentary rocks that were deposited after the belts were juxtaposed by faulting during the waning stages of the Acadian Orogeny (e.g., Ruitenberg and McCutcheon 1982) and subsequent faulting events.

From southeast to northwest, the Precambrian rocks in the southeastern belt consist of fault-bounded units that include felsic Hadrynian volcanic rocks, and minor mafic volcanic and sedimentary rocks (Units HAv and HBv) that have traditionally been assigned to the Central Volcanic Belt of the Coldbrook Group (Ruitenberg et al. 1979), orthogneiss and paragneiss of the Brookville Gneiss (Unit Hg) that has recently been assigned to the Hadrynian (Barr and White, this volume), Helikian limestone, dolomite and quartzite of the Ashburn Formation (Unit Hs), a latest Hadrynian felsic and mafic dyke swarm (Unit Hk) informally referred to as the Kingston Dyke Swarm by McCutcheon and Ruitenberg (1987) and Hadrynian felsic and mafic, tuffaceous volcanic rocks that were assigned to the Western Volcanic Belt of the Coldbrook Group (Ruitenberg et al. 1979).

The present investigation has shown that the rocks previously assigned to the Central Volcanic Belt are divisible into two distinct units bounded by a major fault. The unit south of the fault consists of variably deformed felsic and minor mafic tuffaceous rocks, and minor volcanogenic sedimentary rocks (Unit HAv) whereas those north of the fault are mostly massive, felsic, volcanic breccias with minor thinly laminated, siliceous sedimentary rocks (Unit HBv). In time terms, these may in part be equivalents of the older and younger groups of volcanics, respectively, referred to by Barr and White (1988).

The rocks assigned to the Western Volcanic Belt are tentatively assigned to the older group of volcanics (Unit HAv).

These Precambrian rocks are overlain by Eocambrian and Eocambrian or younger sedimentary and/or volcanic rocks (Units Es and E/Cs) which are in turn overlain by Cambrian sedimentary rocks of the Saint John Group (Unit -€s). A variety of felsic and mafic plutons intrude these Middle to late Hadrynian and Eocambrian rocks based on absolute age dates (Barr and White 1988; Currie 1989). These are collectively referred to as felsic (Unit Hf) and mafic (Unit Hm) intrusions in this report.

From southeast to northwest, the northwestern belt consists of mafic volcanic and sedimentary rocks, and feldspar porphyries designated as Cambrian or younger (Unit -€/Svs) by McCutcheon and Ruitenberg 1987. These rocks are separated from the main Silurian section (Unit S/Osv) by a major fault. The latter unit includes the Queens Brook, which may be all or in part Ordovician in age, and the Silurian Long Reach and Jones Creek Formations that, locally, form a conformable sequence in this area. Formations in the section are commonly repeated by major, northeast-trending, steep- to shallow-dipping faults that typify the unit, particularly toward the northwest. Lenticles of black, pyritiferous shale and quartzite of possible Ordovician age designated as Unit Os(?) and of intensely altered and highly sheared felsic, tuffaceous volcanic rocks of possible Precambrian age designated as Unit HAv(?) also occur along the major northeast-trending fault on the northwest side of the Silurian Belt.

Gold and/or base-metal occurrences are intimately associated with most major faults throughout the area (Figure 26). Many of these faults or fault zones, particularly along the shore of the Bay of Fundy and possibly along the northwestern margin of the Silurian, reflect the brittle effects of terrane accretion. Those to the south are mainly Hercynian structures associated with accretion of the Meguma Terrane of Nova Scotia with the Avalon Terrane of southern New Brunswick (Ruitenberg et al., in preparation). Those to the northwest are likely Acadian structures associated with the accretion of the Silurian belt (Avalon Terrane) against Ordovician rocks of the St. Croix Terrane that outcrops in southwestern New Brunswick. The presence of fault slivers of possible Ordovician age, which resemble St. Croix Terrane rocks (and rocks of possible Precambrian age) along the latter structures, supports the contention that these structures lie near a major terrane boundary.

Other faults that occur within this part of 21 H are viable targets for mineral exploration as is shown by the distribution of gold and/or base-metal occurrences on Figure 26. A good example of a fault zone with gold potential is the boundary between the older and younger Hadrynian volcanic units (Units

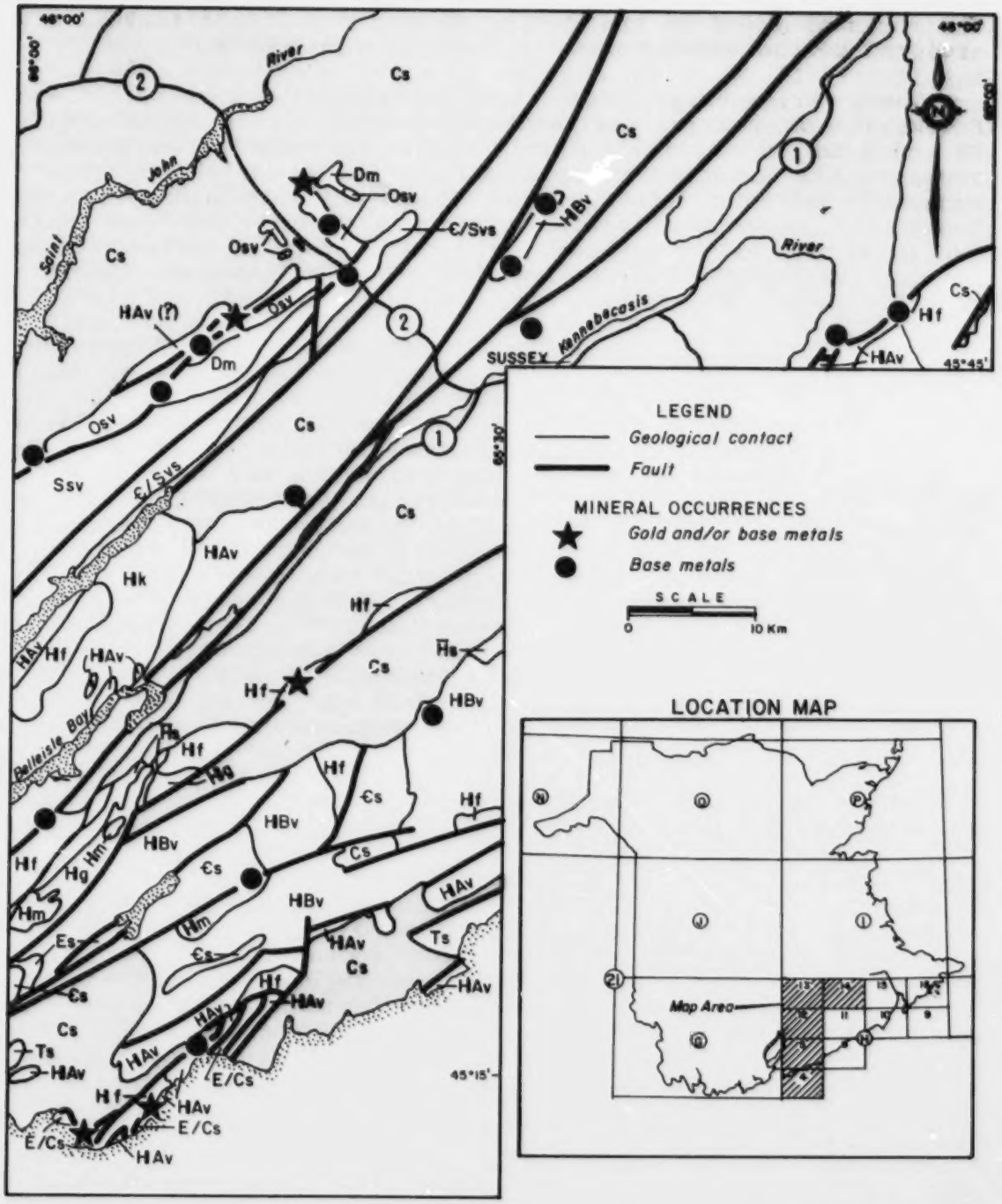


FIGURE 26. Geological map of NTS 21 H/4, 5, 12, 13, and 14.

## LEGEND

TRIASSIC

Ts Sedimentary rocks (Fundy Group)

CARBONIFEROUS

Cs Sedimentary rocks and limestone (Petitcodiac Gp., Lancaster Fm., Tynemouth Creek Fm, Balls Lake Fm., Hopewell Gp., Windsor Gp., and Horton Gp.)

SILURIAN AND POSSIBLE ORDOVICIAN

S/Osv Sedimentary and mafic volcanic rocks (Queen's Brook Fm., Long Reach Fm. and the Jones Creek Fm.)

ORDOVICIAN

Os Sedimentary rocks

CAMBRIAN OR YOUNGER

€/Svs Feldspar porphyry, mafic volcanic rocks and sedimentary rocks

CAMBRIAN

€s Sedimentary rocks (Saint John Gp.)

EOCAMBRIAN OR YOUNGER

E/Cs Sedimentary and minor volcanic rocks (Cape Spencer Fm.*)

EOCAMBRIAN

Es Sedimentary and minor felsic volcanic rocks

DEVONIAN

Dm Mafic intrusive rocks (Stewarton Complex)

LEGEND (cont'd)

PRECAMBRIAN

| | |
|---|---|
| H k | Felsic and mafic dykes (Kingston Dyke Swarm *) |
| H Bv | Felsic volcanic breccia and minor sedimentary rocks (Coldbrook Group) |
| H Av | Felsic and minor mafic volcanic rocks, minor volcanogenic sedimentary rocks (Coldbrook Group) |
| H g | Orthogneiss and paragneiss (Brookville Gneiss) |
| $\overline{H}s$ | Limestone, dolomite and quartzites (Ashburn Formation) |

PRECAMBRIAN

| | |
|---|---|
| H m | Mafic intrusive rocks (Indiantown Gabbro, Duck Lake Gabbro & Otter Lake Pluton) |
| H f | Felsic intrusive rocks (Millican Lake Intrusions, Black River Intrusion, Renforth Pluton, Bonnel Brook Pluton, Upham Mountain Pluton, Point Wolfe River Pluton |

HAv and HBv) in the southern part of the area. The volcanic rocks along this fault are pervasively silicified and carbonatized, and contain abundant pyrite and minor base-metal sulphides. Although no gold has been reported from samples collected in the alteration zone, there is a series of stream-sediment gold anomalies (Geological Survey of Canada 1987) along this structure.

Re-mapping of the Ordovician and Silurian strata in the southwestern part of the Province (21 G), conducted by the writers of this summary in cooperation with L.R. Fyffe, resulted in a revised interpretation and northeasterly extension of the St. Croix Terrane into the Annidale area (21 H). The St. Croix Terrane contains the high-grade "Annidale Copper Deposit" and several gold occurrences of economic interest (Figure 27). Most of these occurrences are related to structures associated with terrane accretion. Extensive trenching was carried out by BP Canada Inc. and Inco Gold Corp. in the northeastern part of the terrane, which greatly assisted the writers in this re-interpretation and delineation of a potentially major gold-bearing zone.

During the course of this compilation and correlation project, an attempt will be made to delineate these and other main ore-bearing structures in southern New Brunswick.

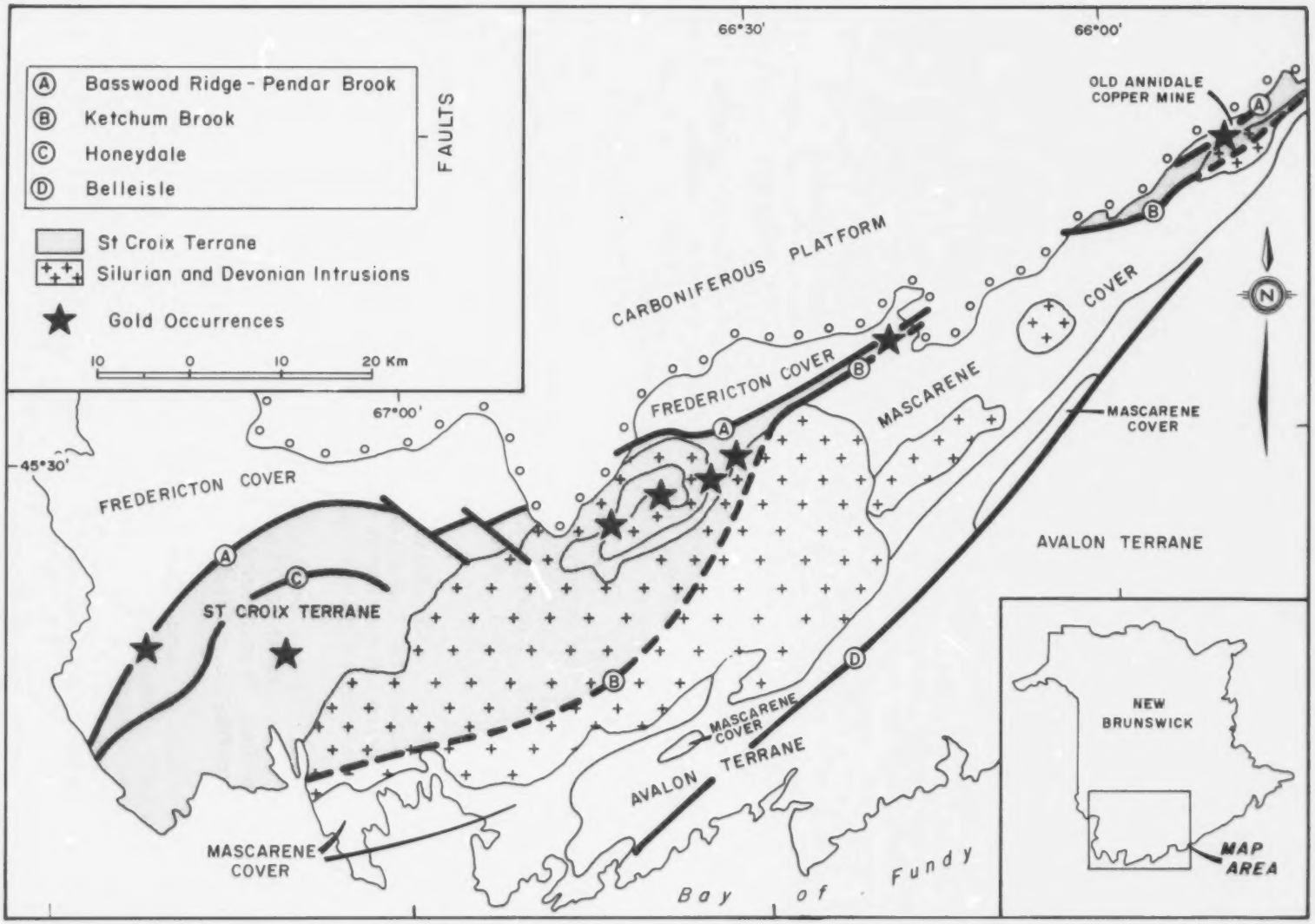


FIGURE 27. Gold potential associated with major fault systems within and along the margin of the St. Croix Terrane.

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# THE LAKE GEORGE ANTIMONY DEPOSIT YORK COUNTY, NEW BRUNSWICK

A.D. Roy, Project Geologist

A project designed to study the structural controls of the Lake George Antimony deposit began in June, 1989. The deposit is a stibnite-bearing quartz vein system that cuts both Upper Silurian greywacke and slate, and a granodiorite stock associated with the Upper Silurian - Lower Devonian Pokiok Batholith.

The main mineralized structure is known as the Hibbard Vein. At the west end of the mine workings, this moderately north- to northeast-dipping vein is offset repeatedly by steep west- to northwest-dipping faults. These faults are parallel to bedding and exhibit mainly reverse and dextral movement. The Hibbard Vein locally transfers to a parallel structure through a connecting quartz-stibnite vein that is parallel or subparallel to bedding. Three main joint sets are: parallel to the Hibbard Vein, parallel to bedding, and parallel to steeply south dipping lamprophyre dykes.

The observed structural relationships are generally consistent with re-activation of a thrust-wrench fault system which resulted in: 1. intrusion of the lamprophyre dykes; 2. emplacement of the Hibbard Vein; and 3. offset of the Hibbard Vein.

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Un projet pour l'étude des contrôles structurales du gite d'antimoine du Lac George a débuté en juin de cette année. Le gite est un systeme de veines de quartz porteuses de stibine et coupant et le grauwacke et l'argillite du silurien superieur, et un stock à granodiorite associé au Batholith Pokiok du silurien superieur associé au dévonien inférieur.

Au bout occidental des travaux de mine, la veine principale minéralisée, la veine Hibbard à pendage modéré au nord à nord-est, est déplacée souvent par des failles à pendages raides vers le nord-ouest. Ces failles sont paralleles au litage et ont un déplacement renversé et dextre. La Veine Hibbard s'étend localement à une structure parallele au moyen d'un veine intermédiaire de quartz-stibnine, laquelle étant parallele ou sous-parallele au litage. Trois unités principales de joints sont: 1) ceux parallels à la veine, ceux parallels au litage, et ceux parallel au dykes à lamprophyre à pendage raide au sud.

Les relations observées de structure s'accordent avec une ré-activation d'un système de failles renversées/transversales qui a produit: 1) l'intrusion des dykes à lamprophyrye, 2) la mise en place de la veine Hibbard et, 3) l'écartement de la veine Hibbard.

A study of the century-old Lake George Antimony Mine, currently owned and operated by Dominion Explorers Inc., located 40 km southwest of Fredericton and 2.5 km north of Lake George, commenced in June of this year. This project is designed to study the structural controls of the deposit to aid exploration for additional ore reserves. Work will continue on this project this winter.

The Lake George Antimony Deposit, as described by Morrissy and Ruitenberg (1980), is a stibnite-bearing quartz-vein system that cuts both Upper Silurian greywacke and slate, and a grano-

diorite stock associated with the Upper Silurian - Lower Devonian Pokiok Batholith (Lutes 1987; Bevier 1988). The system is comprised of three main veins, two of which, the Hibbard and the Prout, have easterly trends with moderate northerly dips. The third vein, the Lawrence, strikes northerly with a moderate easterly dip of about 35°. The Hibbard Vein system, currently being mined, is the main ore-bearing vein. The Prout is known to contain minor ore and the Lawrence is thought to have only small amounts of antimony minerals.

The emphasis of this year's work has been on the structurally complex west end of the mine workings. Here the vein is offset repeatedly by steep, west- to northwest-dipping faults that exhibit mainly reverse and dextral movement. Proceeding westward through this area, the vein orientation changes from its typical north to northeast dip, to east dipping before it is terminated by faulting.

The mineralized quartz vein ranges in thickness from 5 to 20 cm. Stibnite occurs within the vein, both as fillings along fractures and as massive layers parallel to the contacts. Localized brecciation of the Hibbard Vein and host sedimentary rocks occurs along the hanging wall and footwall contacts. The vein locally transfers to a parallel structure through a connecting quartz-stibnite vein that is steeply northwest- or southeast-dipping, parallel or subparallel to bedding. The connecting structures, variably 5 to 25 cm wide, are locally composed of massive stibnite, one of which is extensive enough to have been partially mined in a special shrinkage stope.

In the study area, joints are pervasive in the host sedimentary rocks and form three main sets (Figure 28): one parallels the Hibbard Vein, a second parallels bedding, and a third parallels lamprophyre dykes. A weaker fourth joint set dips steeply northwest or southeast. Local movement has occurred on major and minor faults that parallel the three main joint sets. Mainly reverse movement occurs on minor fault planes parallel to the Hibbard Vein, but both normal and reverse movement is indicated along the Hibbard Vein contacts. Faults parallel to bedding show mainly reverse and dextral movement and minor faults parallel to lamprophyre dykes show evidence of various, but mainly sinistral, movement directions. Bedding and bedding-parallel cleavage, as observed in thin section, dip steeply northwest. Steep, south-dipping lamprophyre dykes display small-scale dextral offset along the Hibbard Vein.

The attitudes and offsets along the faults are generally consistent with a south-directed thrust-wrench fault system (A.A. Ruitenberg, personal communication, 1989). Repeated re-activation of this fault system has resulted in the following sequence of events: 1. the intrusion of the lamprophyre dykes; 2. the emplacement of the Hibbard Vein (and others); and 3. the offsetting of the Hibbard Vein in the

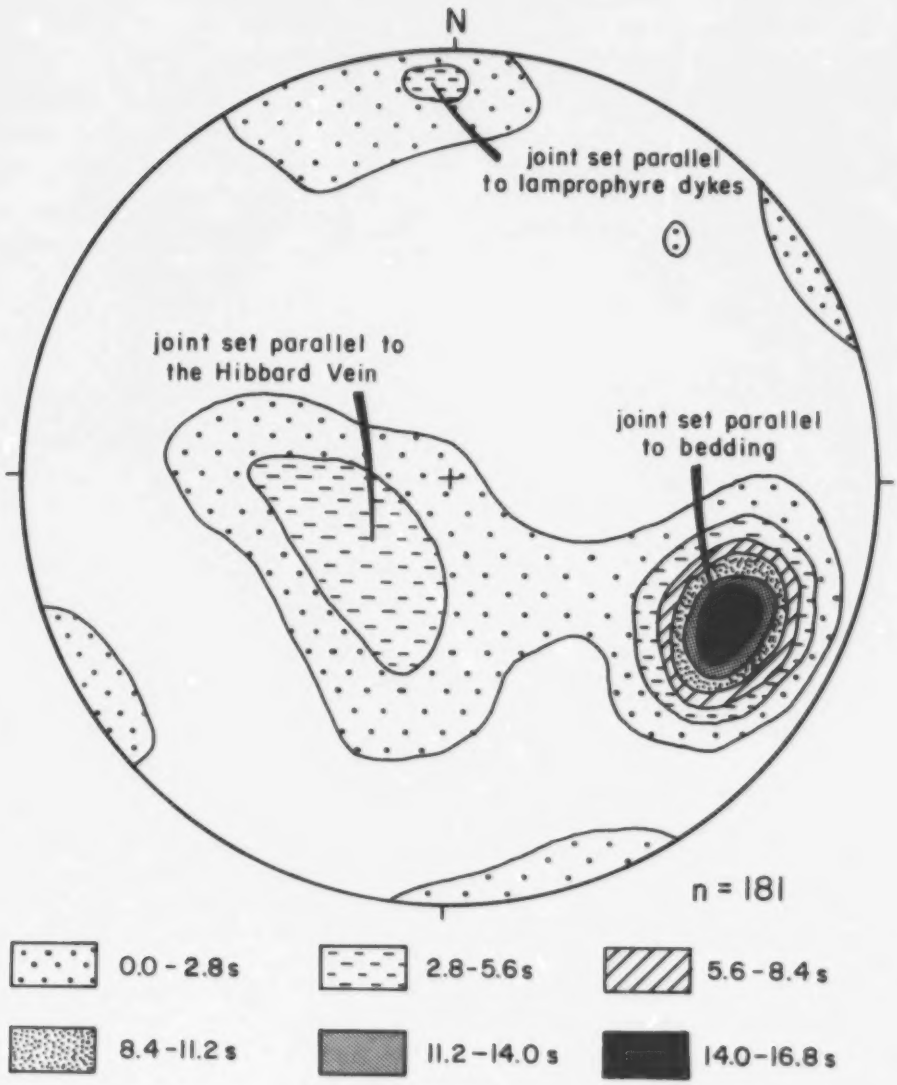


FIGURE 28. Density contour plot for equal-area stereographic projection of poles to joint surfaces. Densities calculated using spherical Gaussian function and contoured in intervals of 2.8 standard deviations after Kamb (1959). Calculations by computer program STEREO (McEachran 1988).

western part of the mine. A detailed strain analysis is planned to test this hypothesis. Also, a regional study is proposed to determine if the intrusion of the Pokiok Batholith occurred along a related major thrust-wrench fault system and/or if this batholith has been displaced by such a fault system. It is notable that large intrusions, such as the Pokiok Batholith, are commonly associated with zones of intense crustal thickening, which could have been produced along a major thrust zone.

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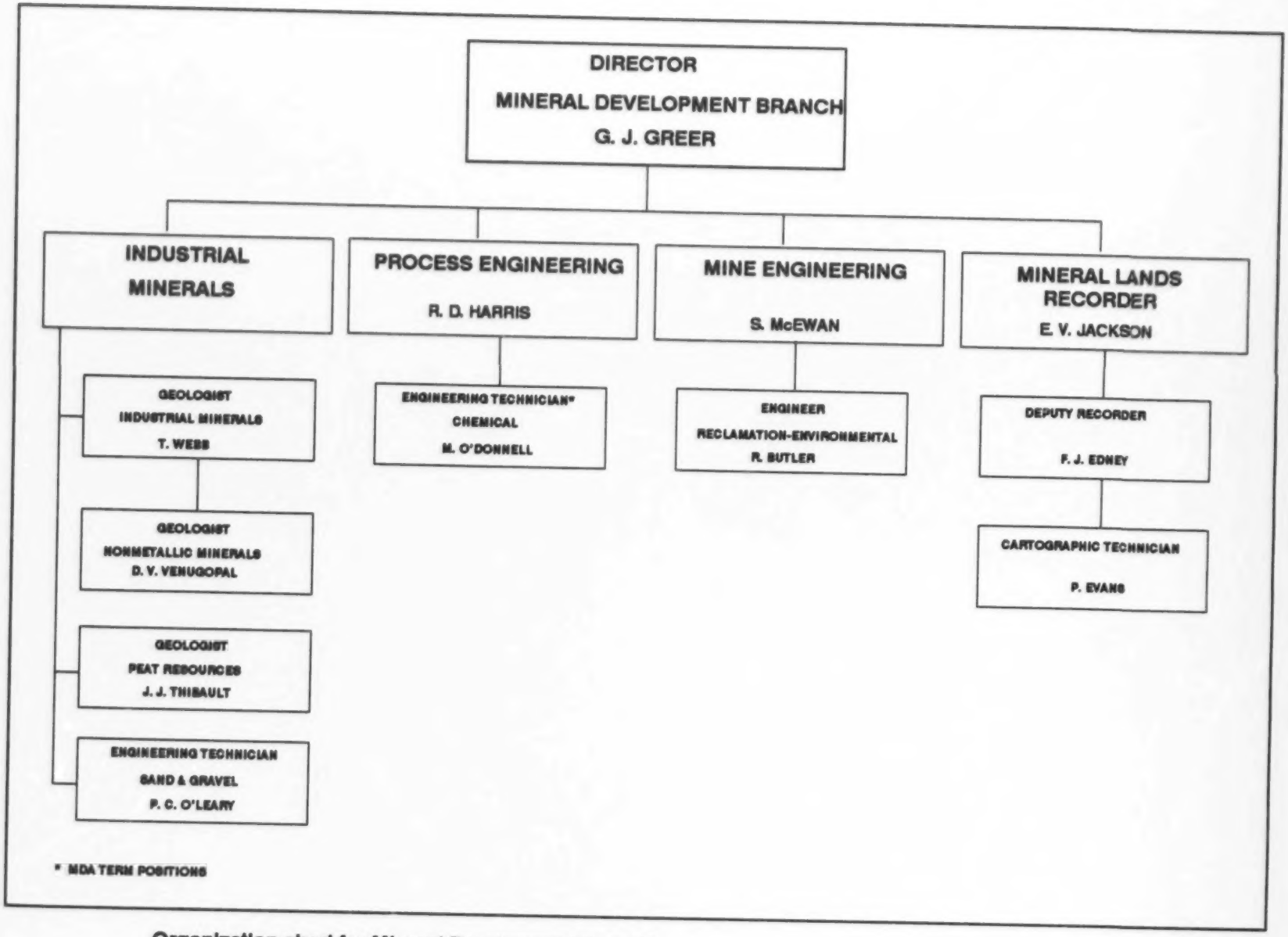
## MINERAL DEVELOPMENT BRANCH




Organization chart for Mineral Development Branch

MINERAL DEVELOPMENT BRANCH

INDUSTRIAL MINERALS SECTION

## PEAT AND COASTAL ZONE RESOURCES

Jacques J. Thibault, Geologist

### PEAT

In 1989, four projects were carried under the Canada - New Brunswick MDA (1984-1989):

1) Assessment of SPOT for application in peatland resource management.

The objective of this project was to test the feasibility of updating 1:10 000 maps of production bogs using SPOT satellite imagery. Work was carried out by GEODAT Information Services Limited of Fredericton. The use of SPOT HRV digital panchromatic band permitted easy delineation of active production surfaces and detection of a high proportion of the drainage network on the bog.

2) Technical information seminar on peat.

The objective of this project was to provide technical information to New Brunwick Peat Producers by inviting experts to present briefs on quality control, marketing, new manufactured peat products, plant management and mining equipment. Work was carried out by the Peat Research and Development Centre of Shippagan. The Seminar was well attended and the proceedings have been published in Open File Report 89-33.

3) Evaluation of ecological constraints on peat mining.

The objective of this project is to obtain base-line information on moose and waterfowl populations in the Escuminac Bog Complex in order to quantitatively evaluate the environmental impact of peat mining on these species. The project has been awarded to the Peat Research and Development Centre of Shippagan and is carried in close cooperation with biologists from Fish and Wildlife Branch of NBDNRE. The project will be completed by March 1990.

4) Peatland Reclamation - Phase II.

The objective of this project is to carry out a field evaluation of reclamation options identified during Phase I of the program. The project has been awarded to the Peat Research and Development Centre of Shippagan and will be conducted in cooperation with two companies now operating on Crown bogs.

Maps depicting the historical development of individual peat operations from 1942 to 1988 have been prepared using aerial photographs. These maps will be released at a later date.

**COASTAL ZONE**

The second of a series of coastal zone videos of the New Brunswick coastline was released by the Geological Survey of Canada as Open File 1979: "The Coast of New Brunswick from Saint John Harbour to Cape Enrage". Other one-hour segments are in preparation.

A paper entitled: "Beach Nourishment, Parlee Beach, N.B." was presented at the Second Regional Workshop on Atlantic Shorelines in Charlottetown, P.E.I. The paper will be published in the proceedings of the workshop.

A report on the coastal geology and geomorphology of Caraquet Island has been prepared and will later be released as a contribution to the Geological Notes Series.

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**TOURBE**

En 1989, quatre projets étaient en cours dans le cadre de l'Entente Canada - Nouveau-Brunswick sur l'Eploitation minérale (1984-1989):

1) Gestion des ressources en tourbe à l'aide des données SPOT.

Ce projet visait à évaluer l'utilité des images satellites SPOT comme moyen de mettre à jour des cartes d'exploitation de tourbière à l'échelle 1:10 000. Le projet a été exécuté par la compagnie GEODAT Information Services Limited de Fredericton. En utilisant la bande panchromatique HRV, il a été possible de définir le périmètre d'extraction ainsi que la presque totalité du réseau de canaux sur la tourbière.

2) Séminaire d'information sur la tourbe.

Le Centre de recherche et de développement de la tourbe a organisé un séminaire d'information à l'intention des producteurs de tourbe du Nouveau-Brunswick. Les conférenciers invités ont abordé plusieurs thèmes notamment le contrôle de la qualité, la mise en marché et l'équipement minier. Le compte-rendu du séminaire a été publié dans le Dossier public 89-33.

3) Impact de l'exploitation de la tourbe sur l'écologie du milieu.

Le but de ce projet est d'obtenir des données de base sur la population d'orignaux et les oiseaux sauvages fréquentant le complexe tourbeux de la péninsule d'Escuminac en vue de déterminer l'impact de l'exploitation de la tourbe sur ces populations animales. L'exécution du projet a été confiée au Centre de recherche et de développement de la tourbe avec la participation de la direction de la chasse et de la pêche sportive du MRNE. Les résultats seront connus à la fin de mars 1990.

4) Restoration des tourbières - phase II.

Ce projet a comme objectif l'évaluation sur le terrain de certaines options de remise en état identifiées dans la phase I du programme. Le projet, dont l'exécution a été confiée au Centre de recherche et de développement de la tourbe, est mené avec la participation active de deux compagnies de tourbe.

Des cartes illustrant l'expansion des différentes entreprises de tourbe entre 1942 et 1988 ont été préparées à l'aide de photographies aériennes. Ces cartes seront publiées à une date ultérieure.

**ZONE COTIERE**

Un deuxième document vidéo se rapportant au littoral du Nouveau-Brunswick a été publié par la Commission géologique du Canada sous le titre de: "The Coast of New Brunswick from Saint John Harbour to Cape Enrage" (Dossier public 1979). D'autres présentations vidéos d'une durée d'une heure sont en préparation.

Une présentation intitulée: "Beach Nourishment, Parlee Beach, N.B." a été faite lors du Deuxième atelier régional sur le littoral atlantique qui se tenait à Charlottetown, I.P.E. au mois de mai 1989. Le rapport sera publié dans les comptes-rendus de l'atelier.

Un rapport sur la géologie et la géomorphologie côtière de l'île de Caraquet a été soumis pour publication dans la série des Notes géologiques.

# INDUSTRIAL MINERAL RESOURCES OF NEW BRUNSWICK

T.C. Webb, Industrial Minerals Geologist[1]

In 1988, industrial mineral production accounted for a 31% share of the total value of mineral production in New Brunswick. The preliminary figure for the value of industrial minerals produced (including cement, lime, and various aggregates) in the Province is about $251 000 000 (Cdn) in 1988, compared to $197 000 000 in 1987. This increase of twenty-two (22) percent is the result of greater potash and peat production. The mining of potash near Sussex has been instrumental in establishing industrial minerals as a major contributor to the Province's mineral wealth. Other industrial minerals produced in New Brunswick include silica, peat, limestone, gypsum, sulphur, salt, sand, gravel, crushed stone, dimension stone, and brick shale.

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En 1988 la production de minéraux industriaux était 31% de la valeux totale de la production minerale totale en Nouveau-Brunswick. Le chiffre préliminaire pour la valeur des minéraux industriels produits (y compris le ciment, le calcaire, et aggrégats divers) dans la Province est environ $251 000 000 (Cdn.) en 1988, vis à vis $197 000 000 en 1987. Cette augmentation par vingt-deux (22) pour cent resulte d'une production aggrandie de potasse et de tourbe. L'extraction de potasse proche de Sussex a été important à établissement les minéraux industriaux comme contribution majeure aux richesses minérales de la Province. D'autres minéraux industriaux produits en Nouveau-Brunswick comprennent la silice, la tourbe, le calcaire, le gypse, le sulfure, le sel, le sable, le gravier, pierre concassé, pierre de construction, et ardoise à brique.

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[1] Please refer to Reference 137: the Preliminary Report on Industrial Mineral Resources of New Brunswick - 1988 by T.C. Webb.

MINERAL DEVELOPMENT BRANCH

MINE ENGINEERING SECTION

## MINE ENGINEERING

S. McEwan, Mining Engineer

Improved base-metal prices have renewed interest in mine development within the Province during the last year. Heath Steele Mines, which had been shutdown in 1984, began production in August and is expected to eventually employ 225 people at a production rate of 2200 tonnes per day. Murray Brook Resources Inc. commenced production at their open-pit gold/silver mine in September, 1989, and will operate at a rate of 1000 TPD with a work force of 25 to 30. Marshall Mineral's Restigouche deposit is currently undergoing an Environmental Impact Assessment prior to its anticipated development in 1990. Marshall will be custom milling at an existing base-metal operation. Stratabound Resources Inc. is in the process of developing a small deposit for custom milling, west of the Heath Steele property.

East West Caribou Mines Ltd. is currently restructuring the ownership and finances of their operation and have found it necessary to shut down for this transition period. Production will recommence in the near future, with a work force of approximately 175 and a production rate of 2500 tonnes per day.

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Des prix ameloirés des métaux à base ont renouvellé l'intérêt dans le développement de mines dans la Province durant l'année passée. La Heath Steele Mines, fermé en 1984, a commencé la production en août et on attend qu'il y aura 225 gens à l'emploi et une productivité de 2200 tonnes par jour. Murray Brook Resources Inc. a commencé la production à leur mine d'or/argent à ciel ouvert en septembre de cette année et travaillera au niveau de 1000 tonnes par jour et 25 à 30 travailleurs. Le dépôt Restigouche de Marshall Minerals est actuellement sous révue pour ses effets sur les environs avant sa mise en production en 1990. Marshall enverra le minerai pour moulinage à un des moulins à minerai existant. Stratabound Resources Inc. fera la même avec le minerai d'un petit gîte sous développement, à l'ouest du terrain de Heath Steele.

East West Caribou Mines Ltée est actuellement à la réstructuration de l'appartenance et des finances de leur opération et ont eu à cesser les trèvaux pendant cette période de transition. La production recommencera tôt et avec à peu près 175 travailleurs et un niveau de production de 2500 tonnes par jour.

The Mineral Development Branch of the N.B. Department of Natural Resources and Energy has a number of specific objectives in its mandate for managing New Brunswick's mineral resources. There is a need to develop the resource in a timely manner using methods that guarantee optimum utilization. This objective is balanced with the requirement that the safety of both the resource and employees is insured, while preserving the environmental integrity of the area.

The Mining Engineering Section of the Branch plays an integral part in ensuring these objectives are achieved. This is accomplished through administration of the Mining Act and involves the following specific tasks:

1. The analysis and assessment of any new mining projects proposed within the Province. This is achieved through the evaluation of feasibility reports, reclamation and waste management plans, as outlined in the Mining Act.
2. The monitoring of existing mining operations through the review of mine plans, site inspections, and statistical analysis of production, labour, and capital expenditures.
3. The monitoring of world markets, economies, and labour relations.
4. The promotion of mining in the Province through the application of Mineral Development Agreements and other forms of monetary and technical assistance.

**NEW MINE DEVELOPMENT**

In 1989, mine development in New Brunswick has significantly increased over past years. This can be attributed to the elevated value of zinc, lead, and copper over the same period. The following is a brief summary of new mining activity that has taken place in the Province during 1989:

**East West Caribou Mining Ltd. (Caribou Zn-Pb-Ag-Cu deposit):**

In December 1986, East West Caribou Minerals N.L. purchased the mineral rights of Anaconda Canada's Caribou Resources Property for approximately $1.0 million (US). Work began on the project in late 1987 and proceeded well until early 1988. At this time the expected equity financing from stock market sources did not materialize, due to lack of investor confidence resulting from the October 19 market crash. Financing for the project was eventually arranged through a five-year limited resource debt package of $30 million, organized through Westpac and the National Australia Bank, and the Royal Bank of Canada. A further $15 million was made available through a silver debenture issue, 50% guaranteed by the Province of New Brunswick. Project development resumed in the second quarter of 1988.

Commissioning of the Caribou mill began in November of 1988 and the first shipment of bulk lead-zinc concentrate (6734 tonnes) left the port of Dalhousie in February 1989 bound for AM&S's smelting facility in Avonmouth, England. The mill exceeded initial design capacity during that period, with higher metal recoveries and mill throughput reaching 2700 tpd., 700 tpd. over design. The mine was officially opened on June 2, 1989 by the Hon. Morris Green, Minister of Natural Resources and Energy and Sir William Keys, Chairman of East West Minerals N.L.

In July of this year, East West Caribou Mining Ltd. ceased production due to a cash flow imbalance. Following the layoff of 60 contract miners, negotiations commenced with the Province and the Australian banks to secure further financing for the

project. In August, it was announced that East West Minerals N.L. had reached an agreement with Bathurst Base Metals Corp. to implement a revitalization plan for the Caribou mine. Breakwater Resources Ltd. of Vancouver was retained to manage the mine. The permanent work force was subsequently reduced to 40 while revisions to the operation took place.

At present, it is proposed that the daily mill throughput be upgraded to 2500 mtpd with a new shaft to facilitate the increased tonnage requirements. When final approval is obtained from the financiers and government for the proposed revisions, the underground operations will commence with milling hopefully starting in the first quarter of 1990.

**Murray Brook Resources Ltd. (a wholly owned subsidiary of NovaGold Resources Ltd.) Murray Brook gold deposit:**

On October 27, 1989 the Hon. Frank McKenna officially opened NovaGold's Murray Brook Mine. The Murray Brook deposit is a massive sulphide deposit with a gold-bearing gossan cap. The gossan contains approximately 1.7 million tons of ore grading .037 oz./ton gold, 1.49 oz./ton silver. The gossan is currently being mined and initial processing results indicate a milling rate of approximately 1150 tpd and recoveries for gold in the +80% range. Both rates are in excess of the original design. The processing facility, one of only three in the world, has features that enhance both its efficiency and environmental integrity. Because it is totally enclosed, ore can be leached on a year-round basis with no characteristic slowdown during the winter months. Enclosure also ensures that airborne or liquid effluents from the operation are strictly controlled. It is expected that gold production will be 15 000 oz. per year over a five-year period, with silver averaging 230 000 oz. annually. Employment at the operation will be 30 people for the life of the mine.

Financing for the operation was completed following the merger of two companies, Northumberland Mines Ltd. and NovaGold Resources Ltd. Initial attempts at acquiring suitable financing by Northumberland had proven ineffective, as did a subsequent equity issue by NovaGold; however, financing was finally put into place in December of 1988, through a limited partnership offer totalling $1.8 million. This, combined with funding already spent on the project, made approximately $4.0 million of debt financing available. The debt financing was backed by a loan guarantee from the federally sponsored Atlantic Canada Opportunities Agency (ACOA). The total capital cost to start the mine was estimated at $6.1 million.

In addition to the present gold production, NovaGold embarked on an exploratory review of the copper portion of the sulphide deposit. Drilling was performed in advance of mining the present open pit. Initial results indicate approximately 330 000 tons grading 4.68% copper. The feasibility of removing

and stockpiling the gossan to enable mining of the copper is being considered.

NovaGold recently announced it had reached an agreement in principle to option the Mount Pleasant base-metals property, currently held by Lac Minerals Ltd. & Billiton Metals Canada Ltd. The option is for 12 months, and may be extended by a further 3 months, exercisable at any time for $12 million. The option price is subject to adjustment based on the current price of tin. NovaGold also agreed to pay Lac's and Billiton's maintenance costs of $20 000 per month during the option period. NovaGold will carry out a feasibility study to evaluate the economic viability of the property.

**Heath Steele Mines (a division of Brunswick Mining & Smelting) (Heath Steele-Stratmat Zn-Pb-Ag-Cu deposit):**

Following an extensive underground exploration program at the Stratmat site, which included bulk sampling and test stoping, a decision was made on February 20, 1989 by Noranda to proceed with the reopening of Heath Steele Mines. Heath Steele is a division of Brunswick Mining & Smelting Corp. Ltd. with both Brunswick and Noranda maintaining controlling interest. Sharing of some common facilities with Brunswick was a major factor in the reopening of the mine. High zinc, lead, and copper prices, combined with an agreement with Cominco to develop the Stratmat Property also contributed to the essential conditions for reopening. The operation was registered under the Environmental Impact Assessment Regulation and screened out with conditions.

The operation is designed to run at a rate of 2200 mtpd, with mill feed coming from three zones on the property (Stratmat, B-Zone, & E-Zone). Once the decision to proceed was made and government approval was obtained, development of the Stratmat open pit began. Production from the pit started in the 3rd quarter of 1989, with some underground extraction taking place as well. The B-Zone has been producing since the 2nd quarter and has supplied ore to Brunswick's mill during the reopening of their No. 3 shaft. Commissioning of the Heath Steele mill is presently underway with full production expected shortly. Early indications suggest very good recoveries for zinc. The mining operation is expected to employ about 220 people when fully operational, with a total capital investment of $27 million and annual operating costs in the range of $27 million, with a payroll of $8.4 million.

Feasibility for the project was based on current reserves lasting a period of five years, however, a number of other deposits exist on the site and the operation will probably run for a longer period. The original capacity of the mill prior to its shutdown in 1983 was 3500 mtpd and with this potential for extra production Heath Steele is in a position to consider

custom milling of other local ores, as a means to improve profits and ultimately extend the life of the operation.

**Marshall Minerals Corp. (Restigouche Zn-Pb-Ag deposit):**

After acquiring the mineral rights to the Restigouche deposit in in March of 1988, Marshall Minerals embarked on an extensive drilling program to further define reserves and processibility of the ore. Results proved favourable and in February 1989 Marshall registered for screening under New Brunswick's Environmental Impact Assessment Regulation and was subsequently screened in. The deposit is situated on Charlotte Brook, which runs into Upsalquitch Lake, a well-known sport-fishing area in a relatively undisturbed part of the Province. Marshall is currently compiling an EIA Report for the project and hopes to receive a positive response from the Lieutenant Governor in Council during the first quarter of 1990.

The deposit is not large enough to support a mill, and therefore, the company has entered into an agreement with East West Caribou Mines Ltd. to process the Restigouche ore. This agreement is contingent upon the results of a bulk sample test, which will be processed at the Caribou site. The bulk sample will be extracted once the decision on the EIA is made. It is expected that it will cost about $3 million to bring the property into production, bringing Marshall's total cost up to $5 million. Production would run at about 750 mtpd from an open-pit operation, employing 25 people for a period of eight years.

**Stratabound Minerals Corp. (Captain North Extension - (CNE) Zn-Pb-Ag-Cu deposit):**

In December of 1987, Stratabound obtained the mineral rights to the Captain North Extension deposit, located approximately seven miles east of the Heath Steele property. During 1988/89, drilling outlined a high-grade, low-tonnage, zinc/ lead/copper/silver deposit close to surface (6 metres). Initial bench-scale metallurgical tests indicate high recoveries and acceptable grade concentrates. Stratabound registered the project under the Environmental Impact Assessment Regulation and the project was subsequently screened out with conditions.

Following the positive EIA screening decision, Stratabound applied to the Department of Natural Resources and Energy to remove a 12 000 tonne bulk sample to test the metallurgy of the ore in a local mill. Removal of the bulk sample is tentatively scheduled for the first quarter of 1990. As the deposit is of relatively low tonnage, the company plans to ship the ore to a local mill and is anticipating an open-pit production rate of approximately 500 mtpd. A production decision is expected upon completion of the bulk test.

## MINE RECLAMATION

R. Butler, Mine Reclamation Engineer

Through the New Brunswick Mining Act and its regulation, all developing mining operations are required to implement a program for the protection, reclamation, and rehabilitation of the environment. The reclamation plan is considered part of the Mine Feasibility Study and is developed during the initial design phase of a mining project. If the reclamation plan is properly engineered it may prevent major environmental impacts from occurring and will result in a mine site that is more readily rehabilitated at a much lower cost to the mining company.

In the administration of the Mining Act, mine reclamation engineering involves:

1) Inspection of existing mining operations in the Province; review of their reclamation practices; and technical support for reclamation programs.
2) The analysis and review of new mining projects in the Province; review of feasibility studies with emphasis on reclamation and rehabilitation; liaison between Natural Resources and Energy, Agriculture, and Municipal Affairs and Environment for assistance in the review of the reclamation program.

Since November 1988, Reclamation Plan approvals have been issued to five companies: Brunswick Mining and Smelting - Heath Steele Mine, East-West Caribou Mining Ltd., Gordex Minerals Ltd., Key Anacon Mining Ltd., and Lafarge Canada Ltd. There is a sixth reclamation plan under review.

Reclamation engineering also involves active research into existing or closed mining operations. The main factors apparent at abandoned mine sites include: reactive acid tailings, acid mine drainage, site safety, and general land rehabilitation. Research is being conducted into methods of alleviating the environmental impact of these sites.

The Province provides financial assistance and offers technical support for various reclamation and rehabilitation programs. Provincial support was given to Brunswick Mining and Smelting for a study to investigate the capping of a waste-rock pile to lower or prevent acid generation at their Heath Steele Mine. The Province is currently supporting a research program concerned with the reclamation of abandoned peat bogs.

The Department of Natural Resources and Energy has representation in the technical working group of the MEND (Mine Environment Neutral Drainage) program.

La Loi Minière et les règles qui en suivent imposent sur tout travail minier l'obligation d'instituer un programme de protection, reconstitution et réhabilitation de l'environment. Le plan de rehabilitation fait partie de l'Etude de Rentabilite et fait partie du dessin initial d'un projèt minier. Si le plan de réconstitution est concu correctement il pourrait éviter des atteintes majeures à l'environnement et donnera un terrain minier plus donné à la réhabilitation et à un côut beaucoup moindre à la compagnie miniere.

Dans l'implémentation de la Loi Miniere la génie de réconstitution implique:

1) L'inspection des travaux miniers dans la Province; une revue de leur processus de restauration; et un support technique pour ces processus.

2) L'analyse et la revue de projets d'études de faisabilité en y accentuant la récuperation et la réhabilitation; une liason entre Ressources Naturelles et d'Energie, Agriculture, et Affaires Municipales et Environnment pour de l'aide dans la revue du programme de réhabilation.

Depuis 1988 des approbations ont été données, pour leur Programme de Réhabilitation a cinq sociétés: Brunswick Mining & Smelting, la mine Heath Steele, East-West Caribou Mining Ltée, Gordex Minerals Ltée, Key Anacon Mining Ltée et Lafarge Canada. On considère actuellement un sixiême plan de réhabilitation.

La génie de réhabilitation implique aussi la recherche avec le bût d'amoindre les résultats néfaste à l'environnement des travaux miniers actuels ou fermés. Les effets principaux aux terrains miniers abandonés renferment: déchets acides réactifs, écoulements miniers acides, la securité aux sîtes, la réhabilitation générale.

La Province donne l'aide financière et offre un support de réhabilitation. Un support provincial a été donné à Brunswick Mining et Smelting pour une étude d'une couverture pour un amoncellement de roches stériles dans le but à diminuer ou prevenir la génération d'acide a leur Mine Heath Steele. La province parraine actuellement un programme de recherche dans l'utilisation de tourbière abandonnées.

Le Ministère des Ressources Naturelles et de l'Energie est représenté dans le groupe de travail (MEND en anglais) sur la neutralisation des eaux de mines.

MINERAL DEVELOPMENT BRANCH

PROCESS ENGINEERING SECTION

# PROCESS ENGINEERING

R. Harris, Senior Engineer

The process engineering section was involved in many activities over the year. These included an assessment of technology for (1) the processing of refractory gold from northern New Brunswick and (2) the recovery of gold from heap-leach solutions at Cape Spencer. The former is being complemented by a follow-up study to assess the refractory resources of the Province and categorize them with respect to their processibility. Other activities involve fine potash recovery via column flotation techniques, administration of the Mineral Investment Stimulation and Mineral Processing Investigations programs, as well as chemical process development work related to the manufacture of potassium sulphate and potassium-magnesium sulphate fertilizers.

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La secteur de la génie des processus a été impliqué dans beaucoup d'activités de processus et activités apparentées pendant l'année. Y compris étaint la mise à l'essai de la technologie pour 1) le traitement de l'or réfractaire du nord du Nouveau-Brunswick et 2) la récupération de l'or des solutions provenant de la lessive en entassement à Cap Spencer. Le premier a un complément dans l'étude conçue à connaitre le démande possible pour ressources réfractaires dans la Province et à classer ces ressources vis à vis de leur traitement. Autres activités comprennent un projet pour la récupération de potasse à grain fin via les techniques le flotation par colonne, l'administration du Programme de Stimulation d'Investissement Minéral (PSIM) et le Programme d'Investigation en Traitement de Minéraux (PITM), et aussi des travaux de développement en processus chimiques vis à vis la manufacture du sulfate de potasse et sulfate de potassium-magnésium en engrais.

Several projects, carried out over the past year, were funded wholly or in part under the current Canada-New Brunswick MDA (1984-1989). These are:

## 1. Processing Options for Refractory Gold Deposits

The study was completed earlier this year by P.J. Whalen, P.Eng., of Fredericton. Lakefield Research (Ontario) was subcontracted to conduct the bench-scale assessment.

Technology for refractory gold processing was reviewed and the three most promising oxidation processes were selected for bench-scale testing; (1) pressure oxidation, (2) biological oxidation, and (3) roasting. Samples from the Corona Elmtree deposit were used for the test program.

Based on the laboratory data, the three processes were evaluated in the context of an in-province custom mill. The economics were based on a plant scale of 75 000 oz./yr. under both integrated and stand-alone plant configurations.

Considering the current price of gold and relative low-grade nature of the bulk sample tested, it is concluded that none of the processes are economical at present. Of the three, biological oxidation shows the best potential. The study was very useful in assessing existing technology and indicating opportunities and constraints.

2. Gold Recovery Options for Cape Spencer Ores

This study was contracted to the Research and Productivity Council (RPC) of Fredericton and is scheduled for completion in late January, 1990.

The objectives are to examine the mineralization of the Cape Spencer gold ore, to review the existing and developing processes for gold extraction and recovery, and to assess their effectiveness. The results will be used to make a preliminary economic assessment.

To date, RPC has bulk sampled the Cape Spencer deposit and completed a thorough literature search of the appropriate processes. RPC is now preparing for the pilot-scale column leaching experiments after completing various bottle roll tests. To date, the results confirm the nonrefractory nature of the gold mineralogy.

3. Column Flotation of Fine Potash

This study was also contracted to the Research and Productivity Council (RPC) and is scheduled for completion in December, 1989. It will be cost-shared between RPC and the New Brunswick Department of Natural Resources and Energy.

Column flotation is gaining prominence as a potentially effective means of recovering "fines" usually not recoverable by conventional agitated flotation. Losses of potash fines to tailings are significant in some potash operations and are becoming a focus for improvement. This work will evaluate column flotation at the Denison-Potacan operation in the Sussex area.

Although the results will directly benefit Denison-Potacan, indirect benefits of the study will include the proving of equipment and testing procedures for assessing column flotation, which then may be applied to other operations in the Province.

An in-plant test column was installed at Denison and is currently being tested within the fines circuit. Preliminary results indicate improved recoveries.

4. Assessment of Refractory Gold Resources

This project has been contracted to 3-D Geoconsultants of Fredericton, based upon their submission of an unsolicited proposal. The work will complement the project entitled, "Processing Options for Refractory Gold Resources", by providing resource data that might support a custom mill.

Activities will include a compilation and assessment of relevant geological and mineralogical data in order to formulate the resource potential of refractory gold deposit in the Province. As well, these resources will be discussed in the context of their potential processibility.

This work began in early fall, 1989 and is scheduled for completion in January, 1990.

5. Mineral Investment Stimulation Program (MISP)

The MISP is a grant program under the Canada-New Brunswick MDA and is designed to fund mineral development projects proposed by industry. Many projects were submitted over the year but, because of the lack of funding, only one project was approved. The project, submitted by Dominion Explorers Inc., will assess potential improvements to their existing surveying system at the Lake George mine.

After consultation with several mining companies and suppliers, Dominion has decided to test two brands of survey instrumentation and to review available computer software. Three promising software packages will be tested to determine which best fits the needs of the company. This project is scheduled for completion in January, 1990.

6. Potassium Sulphate Process Development Project

This project was intended to investigate a possible development concept for add-on processing of potash. The objective was to manufacture fertilizer-grade potassium sulphate and by-product calcium chloride from indigenous potash and gypsum. An extensive prefeasibility study was completed by Cambrian Minerals of the UK, and the Department has actively been promoting the results of this study in an effort to stimulate further development.

As a consequence of remarks from various companies, the Department is now upgrading the current development study for further promotion. Aspects regarding product compaction and granulation are also being addressed.

7. Manufacture of Potassium-Magnesium Sulphate

This is a follow-up from the potassium sulphate project. Its purpose is to determine the economic potential of co-producing potassium-magnesium sulphate.

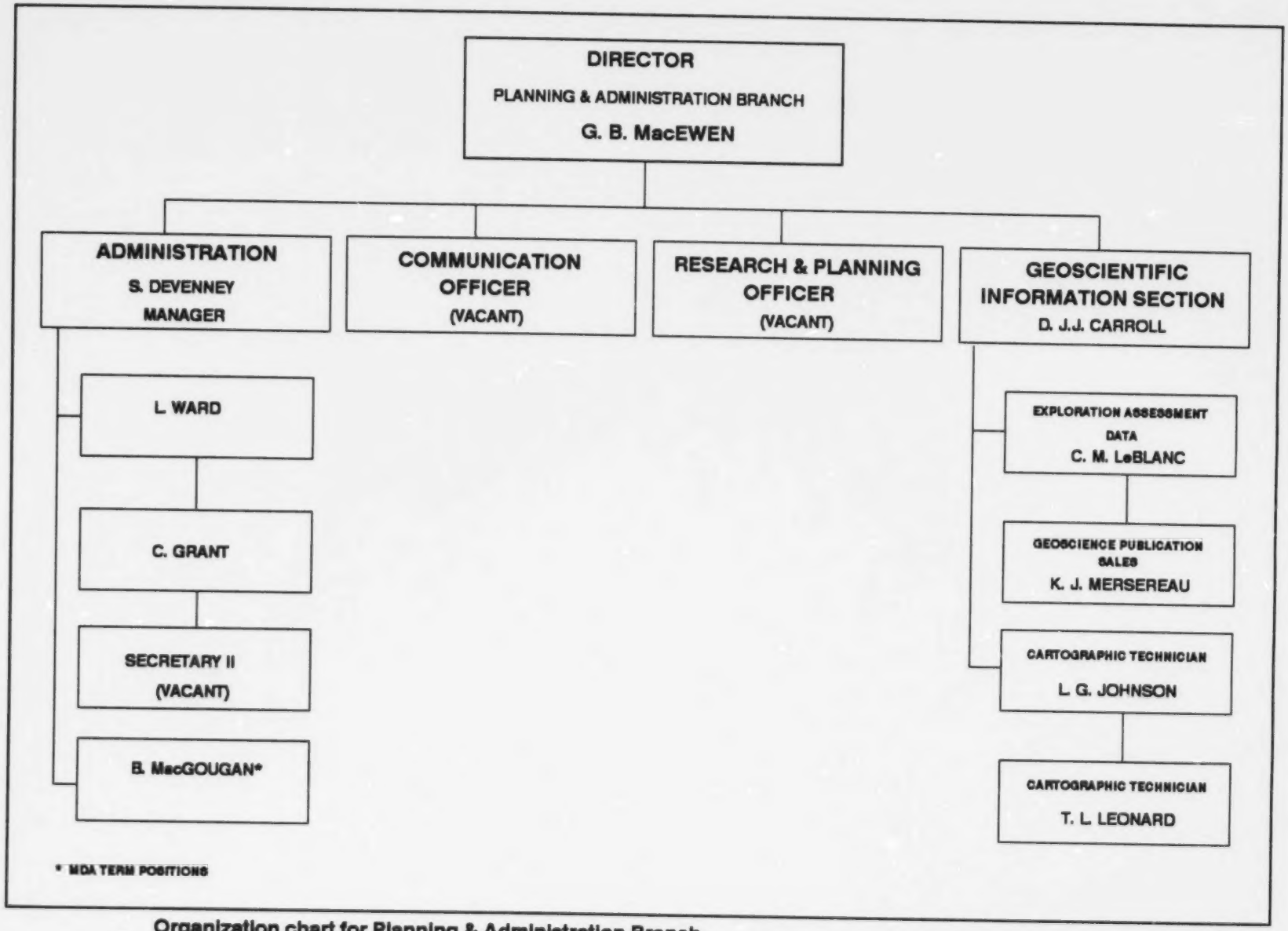
A thorough literature search on the processing and production of potassium-magnesium sulphate for fertilizer purposes was carried out using the computerized Dialog Information System. Several applicable databases were accessed and scanned including CHEM ABSTRACTS, COMPENDEX, SCISEARCH, and CHEMICAL ENGINEERING.

It was concluded that a K-$MgSO_4$ process could not be economically integrated with the $K_2SO_4$ process. However, a stand-alone process based on a reaction of carnallite with gypsum shows some merit, and will be evaluated over the next several months.

8. Mineral Processing Investigations Program

This in-house laboratory program is funded under the current MDA (1984-89). The program included test work on the formation of synthetic wollastonite from limestone and silica, on the extraction of manganese from the Plymouth deposits, and on the recovery of fluorite from Mount Pleasant tungsten ore. Reports on these activities will be prepared in the next year.

## PLANNING AND ADMINISTRATION BRANCH




Organization chart for Planning & Administration Branch

**PLANNING AND ADMINISTRATION BRANCH**

**GEOSCIENTIFIC INFORMATION SECTION**

## ACTIVITIES OF THE GEOSCIENTIFIC INFORMATION SECTION

D.J.J. Carroll, Coordinator

The Geoscientific Information Section consists of the following staff members: Donald J.J. Carroll (Coordinator), L. Gerard Johnson (Cartographic Technician), Terry Leonard (Cartographic Technician), Ken Mersereau (Geoscience Publication Sales), and Carol M. LeBlanc (Exploration Assessment Data).

The Section is responsible for providing a variety of geoscientific, technical, and support services to the staff of the Minerals and Energy Division. In addition, the staff of the Section provide assistance to the public, in particular the mineral industry, by supplying publications on the geology and mineral resources of the Province.

The Geoscientific Information Section is made up of Geoscientific Cartographic Services and Geoscientific Information Services.

The distribution of geoscience publications from the Fredericton office in 1989 totalled 7176 maps and reports. The majority of these sales were to individuals working for the mineral exploration industry.

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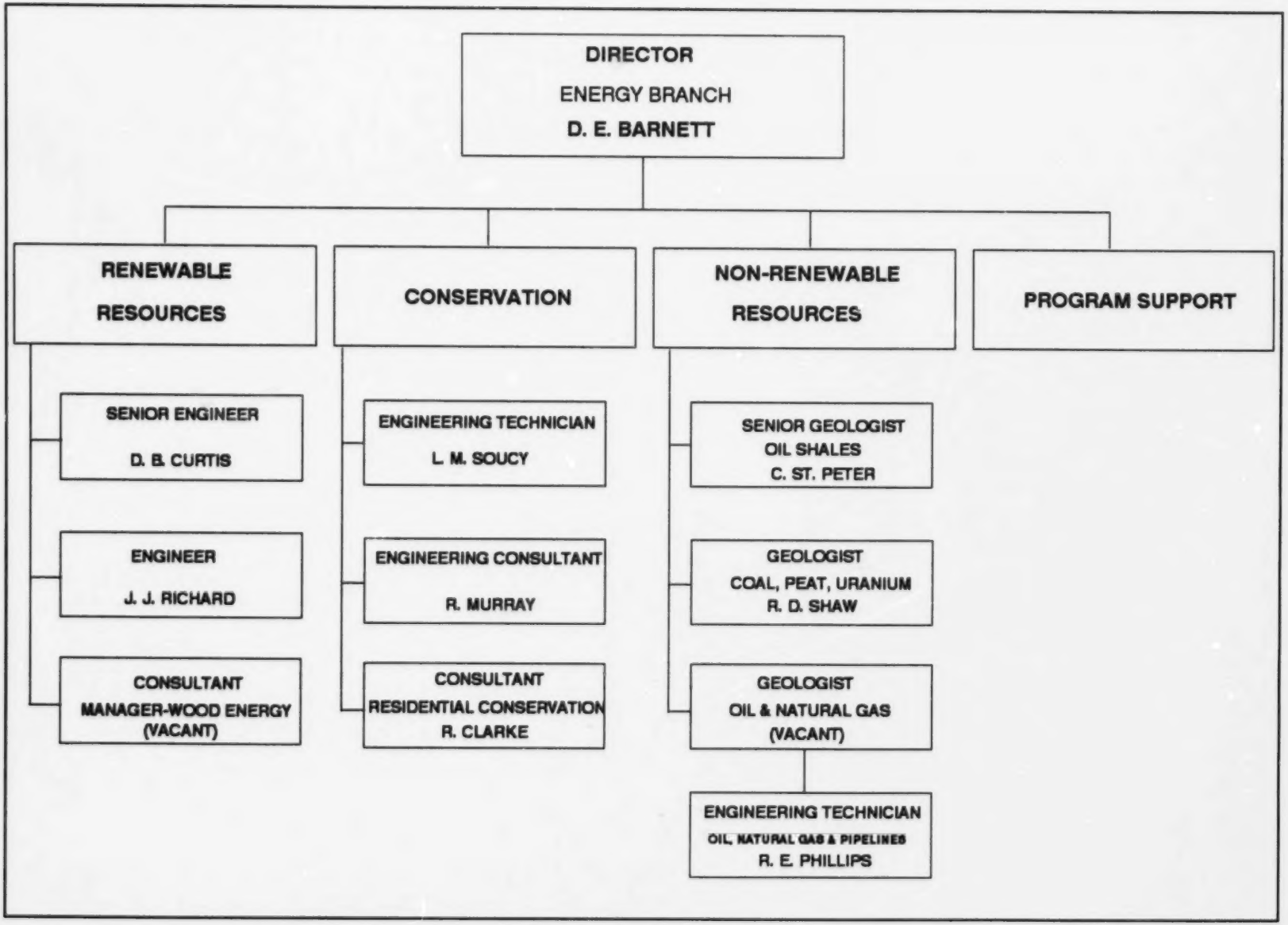
La Section d'information géoscientifiques comprend le personnel suivant : Donald J.J. Carroll (coordonnateur), L. Gerard Johnson (technicien de cartographie), Terry Leonard (technicien de cartographie), Ken Mersereau (vent des publications géoscientifiques) et Carol M. LeBlanc (évaluation des données d'exploration).

La Section doit fournir une foule de services géoscientifiques, techniques et de soutien au personnel de la Division des ressources minérales et de l'énergie. En outre, le personnel de la Section doit offrir au public, et plus particulièrement aux représentants de l'industrie minière, des publications portant sur la géologie et les ressources minérales de la province.

La Section d'information géoscientifique comprend les services de cartographie géoscientifique et les services d'information géoscientifique.

Au cours de l'année 1989, les publications géoscientifiques distribuées par le bureau de Fredericton ont totalisé 7176 cartes et rapports. La plupart des publications ont été vendues à des particuliers travaillant dans l'industrie de l'exploration minière.

## ENERGY BRANCH




**Organization chart for Energy Branch**

**ENERGY BRANCH**

**NON-RENEWABLE RESOURCES SECTION**

# REDBED STRATIGRAPHY IN THE KIERSTEAD MOUNTAIN-MILLSTREAM RIVER AREA, KINGS COUNTY, NEW BRUNSWICK

Clint St. Peter, Energy Geologist

In the past, a redbed sequence in south-central New Brunswick in the Kierstead Mountain-Snider Mountain area has been variously assigned to the Upper Devonian Memramcook Formation, the Lower Carboniferous Moncton Formation, and the Upper Carboniferous Hopewell Group. Field investigations during the summer of 1989 indicate that the red debris flows and water-laid conglomerates and sandstones in question are assignable to the Hopewell Group on the basis of stratigraphic conformity with quartzose conglomerates and sandstones of the overlying and stratigraphically defined Upper Carboniferous Petitcodiac Group.

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Jadis, une séquence de lits rouges se trouvant au sud-central du Nouveau Brunswick, dans la région des monts Kierstead et Snider, a été assignée de façon variable aux Formations Memramcook du Devonien Superieur ou Moncton du Carbonifère Inférieure, et le Groupe Hopewell du Carbonifere Superieur. Les études sur le terrain pendant l'été 1989 indiquent que les coulées de débris rouge et les dépôts sous l'eau de conglomérats et grès ici considérés relèvent du Groupe Hopewell compte tenu de leur conformité stratigraphique avec conglomérats et gres a quartz du Groupe Petitcodiac du Carbonifère Supérieur qui est au dessus et défiré stratigraphiquement.

There are three regionally significant "Carboniferous" redbed sequences in the Moncton Subbasin of southeastern New Brunswick. They are from oldest to youngest the Upper Devonian-Lower Carboniferous Memramcook Formation, the Lower Carboniferous Moncton Formation and the Upper Carboniferous Hopewell Group. The lithological similarity of the three sequences has resulted in numerous incorrect stratigraphic assignments. Incorrect assignments have resulted from uncertain structural settings, the absence of dateable plant fossils (spores) or the absence of marker formations in the local section. Reliable markers include the grey Albert Formation oil shales and sandstones which lie between the Memramcook and Moncton formations, the marine Windsor Group carbonates, sulphates and chlorides which lie between the Moncton Formation and the Hopewell Group, and the quartzose conglomerates and sandstones of the Petitcodiac Group which overlie the Hopewell Group.

The unfossiliferous redbeds that lie in contact with the pre-Carboniferous crystalline "basement" rocks in the Kierstead Mountain-Snider Mountain-McMillan Hill area (Figure 29) are an example of a redbed sequence with a colourful stratigraphic history. Alcock and MacKenzie (1946) placed the redbeds on the southeast side of the Kierstead Mountain basement ridge in the

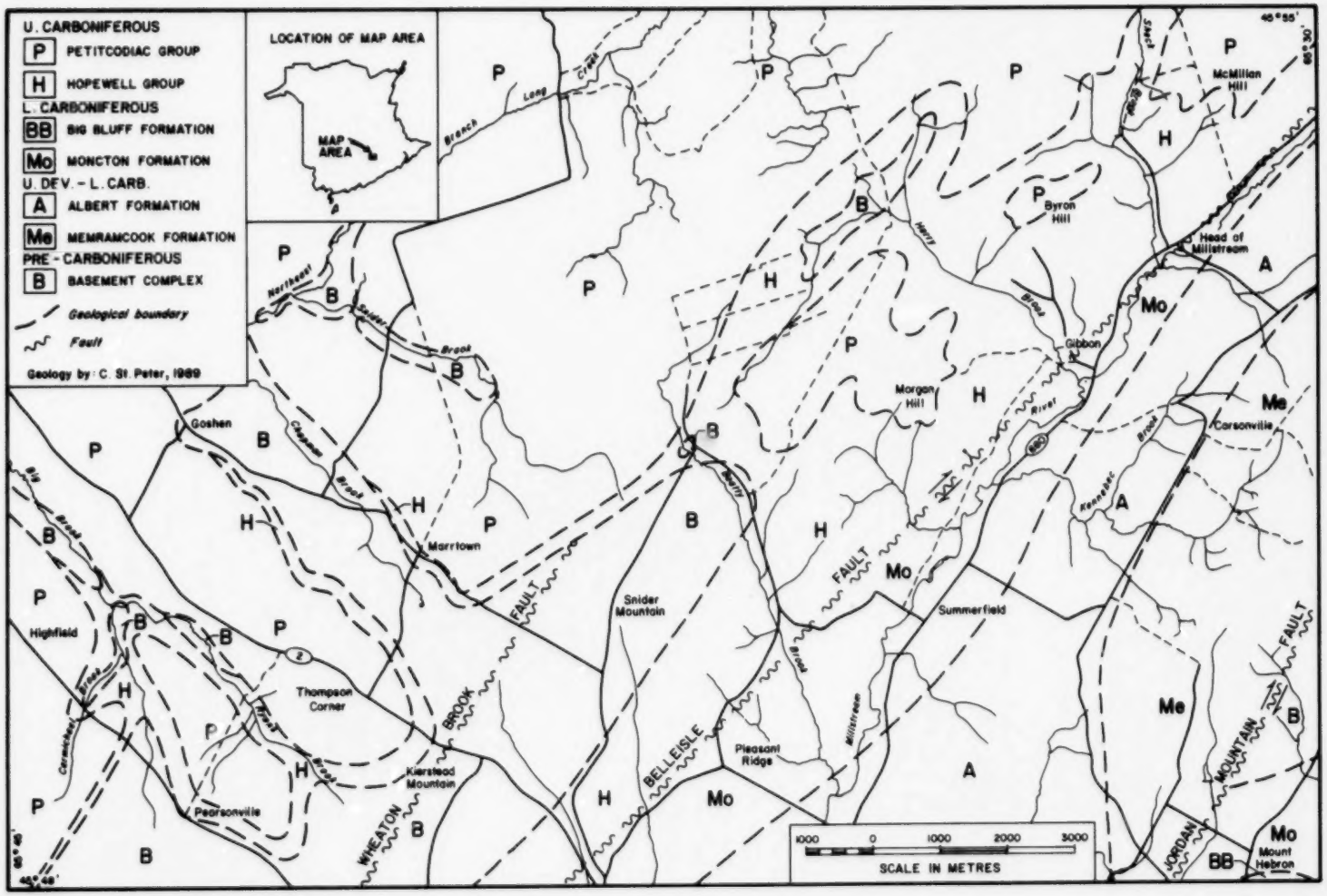


FIGURE 29. Simplified geology of Kierstead Mountain-Millstream River area, New Brunswick.

Moncton Formation. Gussow (1953) assigned the same red conglomerates and sandstones to the older Memramcook Formation on the basis of analogous stratigraphy exposed 30 km to the southeast. Following Gussow's lead, Hamilton (1959) mapped the redbeds on the southeast side of the basement ridge and similar isolated redbed exposures on the north flank of the ridge along Ryans Brook and north of Snider Mountain as Memramcook Formation. In 1987 McCutcheon and Ruitenberg relegated the 00dbeds on the north side of the ridge to the Hopewell Group while retaining the Memramcook assigment for the strata on the south side. With so much ambiguity it was decided in the summer of 1989 to undertake a limited field study to try and resolve the redbed stratigraphy in the area.

The results of the field study are summarized on Figure 29. The redbeds on the north and south sides of the Kierstead Mountain-Snider Mountain basement ridge are lithologically indistinguishable. The rocks are mainly poorly sorted polymictic debris flow conglomerates with lesser water-laid polymictic conglomerates and massive and cross-bedded sandstones. It is believed that the rocks on both the north and south sides of the ridge are part of the Hopewell Group based on the following evidence: (1) the strata lie with stratigraphic conformity below quartzose conglomerates and sandstones of the Petitcodiac Group, and (2) the strata can be "followed" or correlated around the northeast end of the ridge in the Beatty Brook area. With respect to point (1), the isolated redbed exposures as mapped by Hamilton (1959) on the north side of the ridge are seen to be part of a continuous thin sequence immediately below the Petitcodiac rocks. Also, the redbeds on the south side of the ridge (as previously mapped) in the Morgan Hill area are conformably overlain by the Petitcodiac Group, a very unlikely eventuality if the redbeds were part of the older and structurally more highly inclined (or folded) Memramcook or Moncton formation.

In conclusion, the redbeds in the Kierstead Mountain-Snider Mountain area are assigned to the Upper Carboniferous Hopewell Group. In this area, as has been previously demonstrated elsewhere in the Moncton Subbasin, indiscriminately assigning undated rocks to one or another redbed sequence on the basis of regional analogies can lead to needless confusion.

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# PART II

## GEOLOGICAL SURVEY OF CANADA

# RE-INTERPRETATION OF PRECAMBRIAN STRATIGRAPHY, KINGS AND SAINT JOHN COUNTIES, NEW BRUNSWICK (MDA)*

Sandra M. Barr and Chris E. White, Department of Geology, Acadia University, Wolfville, Nova Scotia B0P 1X0

On the basis of new geological mapping, combined with petrological studies and radiometric dating, two tectonostratigraphic terranes are proposed in the Caledonian Highlands east of Saint John. The Brookville Terrane includes the Green Head Group, the ca. 605 Ma Brookville Gneiss, and associated plutons. These units are in faulted contact with the Caledonia Terrane, characterized by three sequences of mainly volcanic and volcaniclastic rocks, overlain by Lower Cambrian sedimentary rocks. Plutons in the Caledonia Terrane are of two ages, ca. 610 - 625 Ma and ca. 550 Ma, and contrast in composition and probably in age with those of the Brookville Terrane.

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À la lumière de la nouvelle cartographie géologique combinée aux études pétrologiques et à la datation radiométrique, deux formations géologiques tectonostratigraphiques ont été proposées dans les Caledonian Highlands à l'est de Saint John. La formation géologique Brookville comprend le groupe Green Head, le Brookville Gneiss, environ 605 millions d'années, et les plutons associés. Ces unités sont en contact faillé avec la formation Caledonian et se caractérisent par trois séquences de roches, principalement volcaniques et volcaniclastiques, recouvertes par de la roche sédimentaire du bas Cambrien. Les plutons de la formation Caledonian sont répartis en deux âges distincts, environ 610 à 625 millions d'années et environ 550 millions d'années, ce qui contraste en composition et probablement en âge avec les plutons de la formation géologique Brookville.

## INTRODUCTION

During the summer of 1989, geological mapping of Precambrian units in southern New Brunswick was continued to the southwest from the area mapped by Barr and White (1988a, b; 1989) to the Kennebecasis River and the city of Saint John (Figure 30). This new mapping, combined with radiometric dating (Bevier 1988 and unpublished data; Bevier and Barr, in press), and petrological studies completed and in progress (Barr and White 1988c; White and Deveau 1989) has resulted in further revision of stratigraphy in the Caledonian Highlands.

Two terranes, termed Brookville and Caledonia, are recognized in the map area. These areas have different lithologic components and are in faulted contact; hence they are termed

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

terranes following the criteria suggested by Coney et al. (1980). The Brookville Terrane is tentatively correlated with the Bras d'Or Terrane of central Cape Breton Island, and the Caledonia Terrane with the Mira Terrane of southeastern Cape Breton Island (Barr and Raeside 1989).

**BROOKVILLE TERRANE**

The Brookville Gneiss, Green Head Group, and associated plutonic units constitute the Brookville Terrane, extending to the northeast from Saint John for a distance of about 35 km (Figure 30). The units of the Brookville Terrane are in faulted contact with volcanic and sedimentary rocks of the Caledonia Terrane to the southeast.

The Brookville Gneiss includes paragneiss with calc-silicate lenses, narrow layers of marble, and granodioritic to tonalitic orthogneiss. The paragneiss is locally migmatitic and contains a low-pressure mineral assemblage (cordierite ± andalusite + biotite + K-feldspar). Late Precambrian U-Pb ages (M.L. Bevier, personal communication, 1989) from the Brookville Gneiss indicate that it is much younger than previously interpreted (e.g., Olszewski and Gaudette 1982).

The Green Head Group, consisting of locally stromatolitic marble, calcareous pelite, and quartzite (Wardle 1978), has not been remapped in detail. Zones of mylonitization are widespread, especially near contacts with the Brookville Gneiss. If the Helikian age of the Green Head Group suggested by Hofmann (1974) on the basis of stromatolites is correct, then the gneiss appears to be younger than the Green Head Group, and hence cannot be considered "basement" to the Green Head Group as has been commonly assumed (Currie 1986; 1987).

The Brookville Gneiss and Green Head Group were intruded by varied plutonic units ranging from gneissic to variably foliated to unfoliated, and from gabbroic to granitic. The late Precambrian age (M.L. Bevier, personal communication, 1989) for orthogneiss in the Brookville Gneiss indicates that less deformed and undeformed plutons in the terrane are younger than about 600 Ma. In the Bras d'Or Terrane of Cape Breton Island, similar dioritic to granitic plutons intruded gneisses and metasedimentary units generally correlated (cf. O'Brien et al. 1983; Nance 1986) with the Brookville Gneiss and Green Head Group, respectively, have yielded ages between about 555 and 565 Ma (Dunning et al., in press). By analogy, the plutons in the Brookville Terrane may be of similar age. If so, they are younger than dioritic to granitic plutons in the Coldbrook Group which have yielded ages between 610 and 630 Ma (Bevier and Barr, in press; Watters 1987). Hence, use of the term Golden Grove Intrusive Suite to include all granitoid plutons in the Avalon Terrane of southern New Brunswick (e.g., Nance 1987; Currie 1989) should be discontinued.

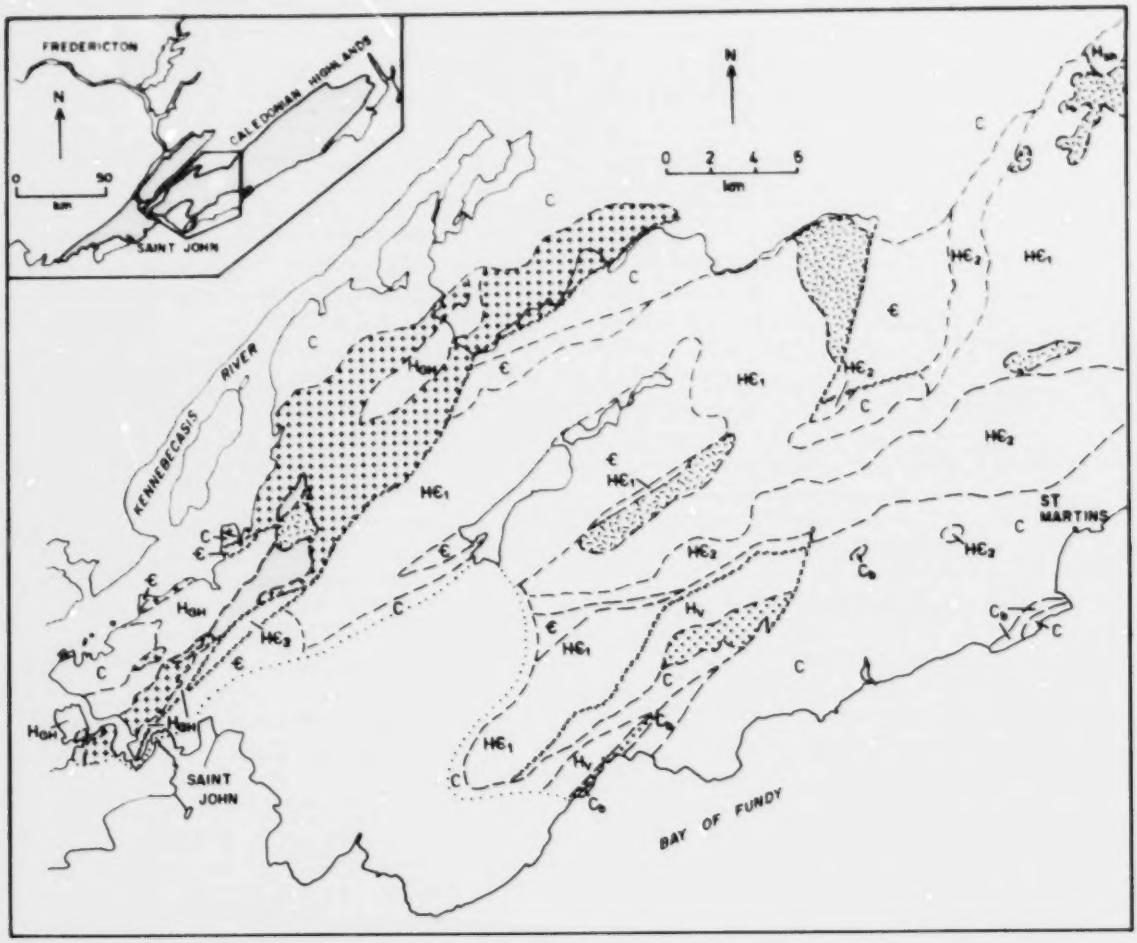


FIGURE 30. Simplified geological map of the southwestern Caledonian Highlands. Dotted line indicates limit of mapping.

**CALEDONIA TERRANE**

The Caledonia Terrane consists mainly of volcanic and sedimentary rocks previously assigned to the Coldbrook Group (Ruitenberg et al. 1979). Slivers of mica schist, albite porphyroblastic schist, and minor marble occur on the northwestern margin of the terrane. Such units may have been the source of ca. 615 Ma muscovite (Dallmeyer and Nance 1989) characteristic of lower Cambrian units in the Caledonia Terrane.

The volcanic and sedimentary rocks of the Caledonia Terrane are divided into three sequences termed Hv, $H\epsilon_1$, and $H\epsilon_2$ and described in the legend of Figure 30. Ages ascribed to these three sequences are based on radiometric dating by Bevier (1988 and unpublished data), Bevier and Barr (in press), and Watters (1987). Sequence Hv (sequence A of Barr and White 1988c) is more abundant in the central Caledonian Highlands, and

## LEGEND

(Note: Subdivisions of major units within the map area are described below but cannot be shown on the scale of this map)

**CARBONIFEROUS AND TRIASSIC**

C Sedimentary rocks

**CARBONIFEROUS OR OLDER**

$C_b$ Epidotized basalt, minor siltstone and limestone

**CAMBRIAN**

$\epsilon$ SAINT JOHN GROUP
Shale, siltstone, sandstone; minor quartzite, limestone

**LATE PRECAMBRIAN - EARLY CAMBRIAN (ca. 550 Ma and younger)**

$H\epsilon_2$
(1) Micaceous siltstone and sandstone (mainly red, locally grey); red conglomerate; quartz/quartzite-pebble conglomerate
(2) volcanogenic conglomerate/tuff, green felsic flows and chert
(3) Interlayered amygdaloidal basalt, basaltic tuff, rhyolite, rhyolitic tuff, dacitic tuff, minor red siltstone
(4) Amygdaloidal basalt flows; locally with interlayered rhyolite like (5) and sedimentary units like (1)
(5) Pink to red to grey, commonly flow-banded rhyolite and rhyolitic tuff. Locally pyritiferous.
(6) Amygdaloidal basalt flows
(7) Interlayered amygdaloidal basalt, basaltic tuff, rhyolite, rhyolitic to dacitic tuff

**LATE PRECAMBRIAN - EARLY CAMBRIAN (ca. 550 Ma and older)**

$H\epsilon_1$
(1) Grey-green dacitic tuffs
(2) Volcanogenic tuff/conglomerate; typically dacitic to rhyolitic subrounded to subangular clasts; colour varies from grey to black to pink to orange (limonitic); black dacitic lapilli and crystal tuffs occur locally
(3) Dark grey to black lapilli and crystal tuffs; dacitic to rhyolitic composition; locally flow-banded
(4) Laminated black to grey to green siliceous siltstone
(5) Green epidotized andesitic rocks; locally includes plagioclase porphyry and green dacitic sheets

LEGEND (cont'd)

LATE PRECAMBRIAN (ca. 600 - 635 Ma)

$H_V$ (1) Pink to red to buff felsic crystal tuff, locally flow-banded; strongly cleaved, minor red siltstone/tuff; dacitic porphyry
(2) Grey intermediate crystal tuff; strongly cleaved

$H_{sh}$ Mica schist, albite porphyroblastic schist (locally garnet-bearing), minor marble

BROCKVILLE GNEISS:
Banded cordierite-biotite K-feldspar migmatitic paragneiss, cordierite-andalusite-biotite-K-feldspar paragneiss, hornblende-bearing paragneiss, granodioritic to tonalite orthogneiss and marble

HELIKIAN (?)

GREEN HEAD GROUP:
$H_{GH}$ Marble (locally stromatolitic), calcareous pelite and quartzite

PLUTONIC UNITS

LATE PRECAMBRIAN - EARLY CAMBRIAN (ca. 550 Ma)

Bonnell Brook Pluton (spherulitic rhyolite, granophyric syenogranite, syenogranite)
Upham Mountain pluton (granophyric syenogranite, local diorite/gabbro)
Baxters Mountain pluton (mixed gabbro, diorite, syenogranite)
Duck Lake Pluton (gabbro)

LATE PRECAMBRIAN - EARLY CAMBRIAN (ca. 560 Ma??)

Fairville, Chalet Lake and Hammond River plutons (coarse-grained, locally foliated monzogranite/granodiorite with megacrysts of K-feldspar)
Rockwood Park Pluton (medium-grained foliated granodiorite)
Narrows, Milkish Head and Mayflower Lake plutons (medium-grained, locally foliated, granodiorite to quartz diorite)
French Village Pluton (varied dioritic rocks ranging from quartz diorite to diorite and gabbro)
Unnamed gneissic granitoid rocks (may be in part equivalent to Rockwood Park and Fairville plutons)

LATE PRECAMBRIAN (ca. 610 - 625 Ma)

Deformed granitoid rocks

only small areas of cleaved crystal tuff in the southeastern part of the present map area are assigned to this package. These rocks are intruded by calc-alkalic dioritic to granitic plutons with ages ca. 610 - 625 Ma (Barr and White 1988c; Bevier 1988; Bevier and Barr, in press).

Volcanic and sedimentary rocks of sequence H$\epsilon_1$ form much of the 1989 map area (Figure 30) and are generally less deformed and metamorphosed than those of sequence Hv. Distinctive dark-coloured lapilli and crystal tuffs and volcanogenic lithic tuff/conglomerate are typical of this package. These rocks occur in the "type area" of the Coldbrook Group northeast of Saint John. The absolute age is not yet known but radiometric dating is in progress. The minimum age is 550 Ma based on the age of the Bonnell Brook syenogranite (Bevier 1988; Bevier and Barr 1989) that intruded these rocks.

Sequence H$\epsilon_2$, dominated by basalt and rhyolite flows, is inferred to overlie the above rocks. Based on mapping to the east, Barr and White (1988a, b; 1989) assumed that these units form a continuous sequence (sequence B of Barr and White 1988c) with sequence H$\epsilon_1$; however, mapping in 1989 showed that this is not the case. The age of this package is based on a ca. 550 Ma age for rhyolite flows in the central Caledonian Highlands (Bevier and Barr, in press). These rhyolite flows appear to be co-magmatic with felsic units of the Bonnell Brook Pluton (Barr and White 1988c). Although in places separate basalt, rhyolite, and redbed units can be mapped, other units in sequence H$\epsilon_2$ consist of interlayered basalt, rhyolite, and/or sedimentary rocks.

Commonly overlying these units are distinctive maroon quartz and quartzite-pebble conglomerate and micaceous red sedimentary units, previously assigned to the lower Cambrian Ratcliffe Brook Formation (Tanoli et al. 1985; McCutcheon 1987). These rocks are interpreted to be correlative with similar units in southeastern Cape Breton Island (Barr et al. 1989).

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# PRELIMINARY U-Pb GEOCHRONOLOGIC RESULTS FOR IGNEOUS AND METAMORPHIC ROCKS, NEW BRUNSWICK (MDA)*

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Preliminary results of a U-Pb study on zircons are as follows (Ma): Mulligan Gulch porphyry, 491±1; Upsalquitch River bridge porphyry, 401±1; Gibson Granodiorite, 473±1; Utopia granite, 430±3; Welsford peralkaline granite, 422±1; Magaguadavic granite, 396±1; Mount Douglas granite, 366±1; Caledonian Highlands felsic metatuff, 613±2; Caledonian Highlands intermediate metatuff, 600±1.

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Les résultats préliminaires de l'étude U-Pb des zircons sont les suivants (Ma): porphyre de Mulligan Gulch, 491±1; porphyre de Upsalquitch River bridge, 401±1, granodiorite Gibson, 473±1; granite Utopia, 430±3; granite hyperalkalin de Welsford, 422±1; granite de Magaguadavic, 396±1; granite de Mount Douglas, 366±1; tuf métamorphique felsique de Caledonian Highlands, 613±2; tuf métamorphique intermédiaire de Caledonian Highlands, 600±1.

This contribution summarizes the preliminary results of a U-Pb geochronologic study of selected rocks in New Brunswick. The purposes of this research are: a) to obtain precise crystallization ages for a variety of igneous and meta-igneous rocks in the Province of New Brunswick; and b) to use these data to constrain petrologic, tectonic, and metallogenic studies.

Sample localities are shown in Figure 31. Complete analytical results, detailed procedures, and interpretations will be published elsewhere. Ten preliminary U-Pb ages are listed in Table 4, and the results are briefly discussed below.

Two high-level porphyries from the Tobique-Chaleur belt yield ages of 419±1 Ma and 401±1 Ma. McCutcheon and Bevier (in preparation) discuss the constraints that these ages place on the timing of Au mineralization associated with intrusion of the porphyries.

The Gibson Granodiorite, one of the Woodstock stocks, was previously thought to be Devonian in age. Zircons and brown sphenes from the Gibson Granodiorite, however, give an age of 473±1 Ma (Middle Ordovician). Sphene from the Gibson Grano-

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

diorite is zoned from brown to colourless, and the colourless sphenes yield an age of 457±1 Ma. This is tentatively interpreted as the age of a later metamorphic event.

Four new ages from the Saint George Batholith demonstrate that it has both Silurian and Devonian phases (McLeod and Bevier, in preparation). The Utopia granite, with a discordant zircon regression age of 430±3 Ma, may be the oldest phase in the Batholith. Two phases of the Mount Douglas granite are Late Devonian in age.

A felsic meta-tuff and an intermediate composition meta-tuff from volcanic-sedimentary sequence A in the Caledonian Highlands (Barr and White 1988) yield Late Proterozoic ages. A detailed explanation of these ages and other U-Pb results from this area, and their significance in terms of the stratigraphy and tectonic history of the Avalonian terrane, is found in Bevier and Barr (1989).

**NOTE:** Figure 31 is on the following page.

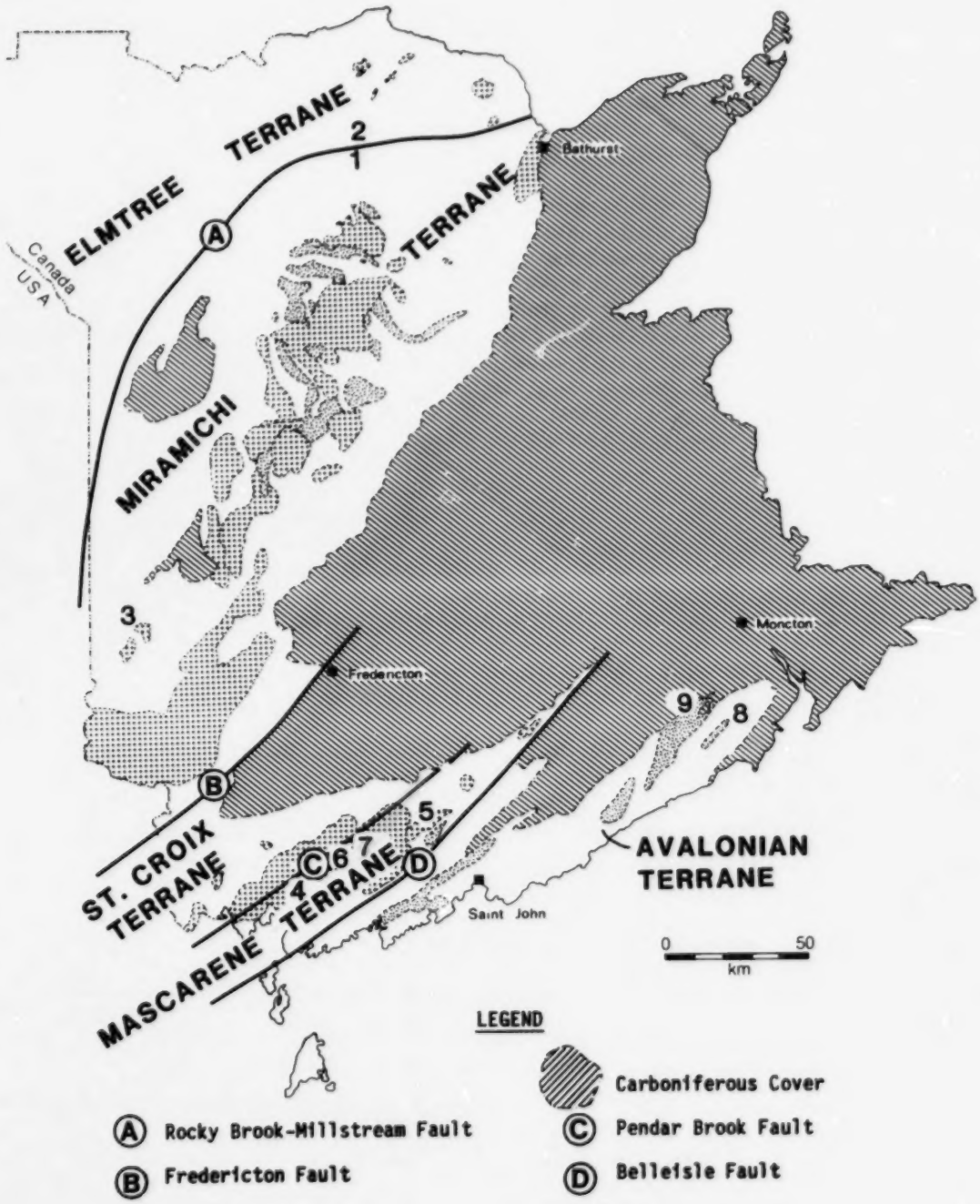


FIGURE 31. Map of plutons in New Brunswick, with sample numbers keyed to Table 4. Terrane boundaries after Fyffe and Fricker (1987).

## TABLE 4

## PRELIMINARY U-Pb AGES, NEW BRUNSWICK

| NAME | U-Pb AGE (Ma) |
|---|---|
| **Tobique-Chaleur Belt** | |
| 1. Mulligan Gulch porphyry | 491±1 |
| 2. Upsalquitch River bridge porphyry | 401±1 |
| **Miramichi Terrane** | |
| 3. Gibson Granodiorite | 473±1<br>457±1 (clear sphene) |
| **St. Croix-Mascarene Terrane** | |
| 4. Utopia granite | 430±3 |
| 5. Welsford peralkaline granite | 422±1 |
| 6. Magaguadavic granite | 396±1 |
| 7. pink seriate phase, Mount Douglas granite | 366±1 |
| **Avalonian Terrane** | |
| 8. felsic meta-tuff | 613±2 |
| 9. intermediate meta-tuff | 600±1 |

Quoted errors are two standard errors of the mean.

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# SEDIMENTOLOGY, DIAGENESIS, AND ORGANIC GEOCHEMISTRY OF THE ALBERT FORMATION, ALBERT COUNTY, NEW BRUNSWICK (MDA)*

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Study of the Albert Formation sandstone detritus, sandstone geochemistry, and paleocurrent data suggests that the detritus was derived from both the Caledonia and Westmorland Uplifts. Depositional environments interpreted from core analysis indicate that the Albert Formation sediments were deposited in braided stream channels, fan deltas, and shallow to deep lakes. Carbon and oxygen isotope analyses of calcite and ankerite cements in the sandstones suggest that the calcites precipitated from near-surface waters and the ankerites from modified connate/meteoric water in the zone of methanogenesis. A time-temperature model suggests that the calcites were formed at a temperature of up to about 70°C and ankerite at 125°C. Organic geochemical studies suggest that the Albert oils are derived mainly from higher plant materials with a low contribution of algae, and the oil started generation at 75°C about 352 million years before present.

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L'étude des détritus, de la géochimie des grès et des données sur les paléo-courants des grès de la formation Albert, suggère que les détritus proviennent des deux surlèvements, le Calédonien et le Westmoreland. Les environnements de déposition, d'après l'interprétation des carottes, indique que les sédiments de la formation Albert ont été déposés dans des chenaux entrelacés de ruisseaux, des deltas et des lacs peu profonds à profonds. Des analyses isotopiques sur le charbon et l'oxygène de la calcite et l'ankerite du grès suggèrent que les calcites ont été précipités de l'eau proche de la surface et les ankerites des eaux modifiées innée/météorique dans la zone de méthano-genèse. Les extrapolations des données sur temps et température suggèrent que les calcites ont été formés à des températures jusqu'à environ 70°C et l'ankerite à 125°C. L'étude géochimique organique suggère que les pétroles Albert dérivent, pour la plupart, des plantes plus évoluées, avec un faible apport des algues. Le commencement de la géneration était à 75°C il y a environ 352 millions d'années.

The original project on the diagenesis of the Albert Formation was completed in May, 1988 and the results are available in Geological Survey of Canada open file report 1997 (Chowdhury and Noble 1989). The project terms of reference have been expanded and detailed analyses of sedimentologic aspects of the Albert Formation are continuing. Results (e.g., provenance, depositional environment, sandstone diagenesis, burial history, time-temperature modelling and petroleum geochemistry) of the project are summarized here.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

**PROVENANCE**

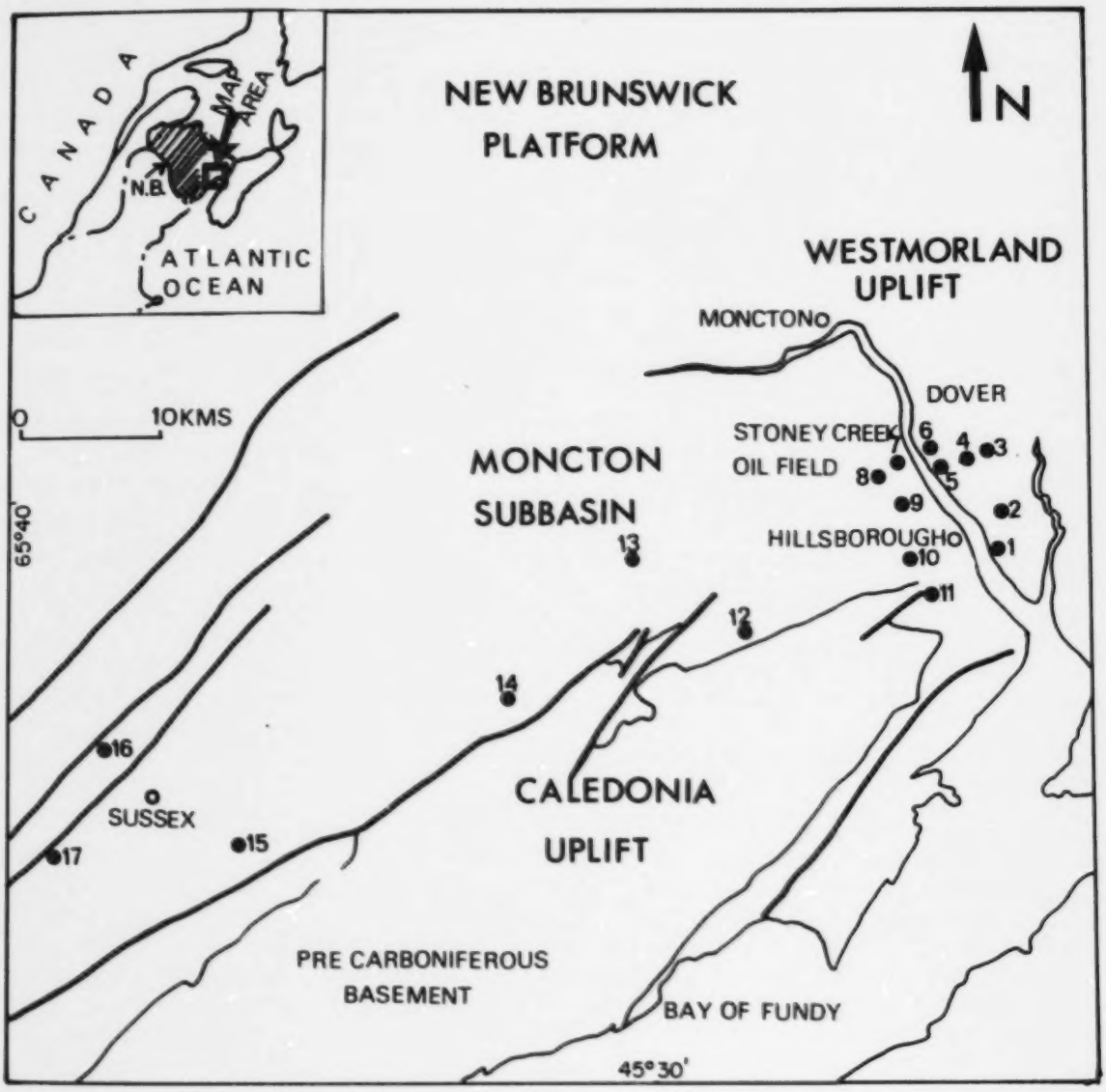
Provenance of the Albert Formation sandstones has been studied by thin-section petrography and major- and trace-element geochemistry. Quartz/Feldspar/Rock Fragment plots on classical tectonic provenance diagrams (Dickinson and Suczek 1979) suggest that the sandstones are derived mainly from recycled orogenic provenances with a minor contribution from continental blocks. Based on these data, it is suggested that the Albert Formation sandstones were derived from adjacent uplifts (e.g., Caledonia and Westmorland uplifts). This conclusion is in agreement with paleocurrent data measured mainly from ripples and small scale cross-beds. Paleocurrent data in the east of the Subbasin generally show a SW direction, in the south a general NE direction, and in the west a general NE direction (C. St. Peter, personal communication, 1989) suggesting that the sandstones were derived from both the Caledonia and Westmorland uplifts.

An attempt was made to chemically characterize the possible source terrains of the Albert Formation sandstones. Major-element data of the sandstones from different areas of the Subbasin do not show any chemical variation, suggesting that the sandstones were derived from chemically identical source terrains. The corrected (CaO and L.O.I. free) high $Na_2O$ (up to 5.6%) and low $K_2O$ (up to 3.29%) contents of the sandstones suggest that the sands were derived from a quartz diorite/granodiorite type source terrain. Such rocks are common in the Caledonia Uplift. Trace chemistry of the sandstones also compares well with the Caledonia plutons (quartz diorite/granodiorite; Barr and White 1988) but not with the metavolcanics. Thus the detrital mode, paleocurrent and sandstone composition data suggest that the Albert formation sandstones were derived from both Caledonia and Westmorland uplifts.

**DEPOSITIONAL ENVIRONMENT**

Albert Formation sandstones have been examined from cuttings from recently drilled wells (Irving Chevron's Stoney Creek - 1, East Stoney Creek - 1, Hillsborough - 1 and Lee Brook - 1) (Figure 32) in the central part of the Subbasin. Six lithofacies have been identified (conglomerate, pebbly sandstones, massive sandstones, ripple/cross-laminated sandstones, siltstone and shale, and oil shale). Lithofacies associations suggest that the regional depositional environments are shallow-braided stream channels, fan-deltas, and shallow to deep lacustrine.

The fine sediments from different parts of the Subbasin have been studied for organic matter type and organic carbon content. Organic matter type of the fine sediments from the central and the western wells of the Subbasin are mainly type III to type II (terrestrial material with minor alginite A) whereas the organic matter near Albert Mines in the southeast




| | | | |
|---|---|---|---|
| • | borehole | — | fault |
| 1 | Petro-Canada Boudreau-1 | 10 | Can-Oxy Shenstone-1 |
| 2 | Arco Boudreau-1 | 11 | Can-Oxy Albert Mines-9 |
| 3 | Cartago Dover-1 | 12 | Arco Rosevale-1 |
| 4 | Petro-Canada Dover-1 | 13 | Irving-Chevron Little River-1 |
| 5 | Arco Dover-1A | 14 | Irving-Chevron Lee Brook-1 |
| 6 | Petro-Canada Dover-2 | 15 | United Pan Canadian McLeod Brook-1 |
| 7 | Irving-Chevron E. Stoney Crk-1 | 16 | Gulf Lower Millstream-1 |
| 8 | Irving-Chevron Hillsborough-1 | 17 | Shell Apohaqui-1 |

FIGURE 32. Major tectonic elements of southeastern New Brunswick showing location of studied boreholes cutting significant thicknesses of the Albert Formation, Moncton Subbasin.

part of the Subbasin is primarily type I (lamalginite B). Organic carbon content averages more than 5% in the Albert Mines area, whereas in the central part of the Subbasin it averages less than 2% and in the western part less than 1%.

The central wells show local occurrences of thin to thick beds of oil shales. These oil shales were probably formed during high levels and expansion of the deep lake located in the southern part of the Subbasin. Two periods of lake sedimentation representing fluctuating lake levels are recognized. During times of lake expansion, a large part of the Subbasin deposits were deep lacustrine facies, but during contraction, the lakes were confined to palaeo-depressions and resulted in the development of large expanses of marginal lacustrine and mudflat areas with minor deep lacustrine facies. Thus a ponded lake model is postulated for the Albert Formation.

**DIAGENESIS OF SANDSTONES**

Common diagenetic minerals in the Albert Formation sandstones are chlorite, calcite, quartz, and ankerite. Paragenesis of the minerals is presented in Figure 33.

Quartz constitutes up to 5% of the rock volume and occurs as syntaxial overgrowths, and mega and druse quartz. Syntaxial quartz is early diagenetic in origin, whereas the mega and druse quartz are generally post-solution in occurrence. The syntaxial quartz formed from meteoric water, whereas the mega and druse types formed from mixed meteoric and connate waters.

Carbonate cements are composed of both calcite and ankerite, and together they account for from 2% to about 30% of the sandstone volume. Calcite cements are Fe and Mg poor, whereas the ankerite contains about 17% Fe and up to 18% Mg (by weight). Two phases of ankerite are present. Phase-2 ankerite is rare and is partly derived from phase 1 as evident from the close association and the partial dissolution of phase-1 ankerite. Ankerite in the shales averages 18.33% (N = 12) whereas in the sandstones it averages 8.25% (N =24). Ankerite shows an inverse relationship with calcite. High calcite is accompanied by low ankerite, and vice versa. This suggests that much of the ankerite occupies pore spaces initially filled by calcite, and ankeritization has taken place by solution-reprecipitation processes.

Calcite cement $^{18}O$ values range from - 10 to -18% PDB and for ankerite they vary from -8 to -14% PDB. $^{13}C$ values of calcite vary from - 0.58 to -4.45% PDB whereas they vary from +0.04 to 4.20% PDB in ankerite. $^{18}O$ values of calcite suggest that it is formed from meteoric water; $^{18}O$ for ankerite indicates a probable origin from modified meteoric/ connate water. Carbon isotope values suggest that calcite cements derived their carbon signature from soil-charged near

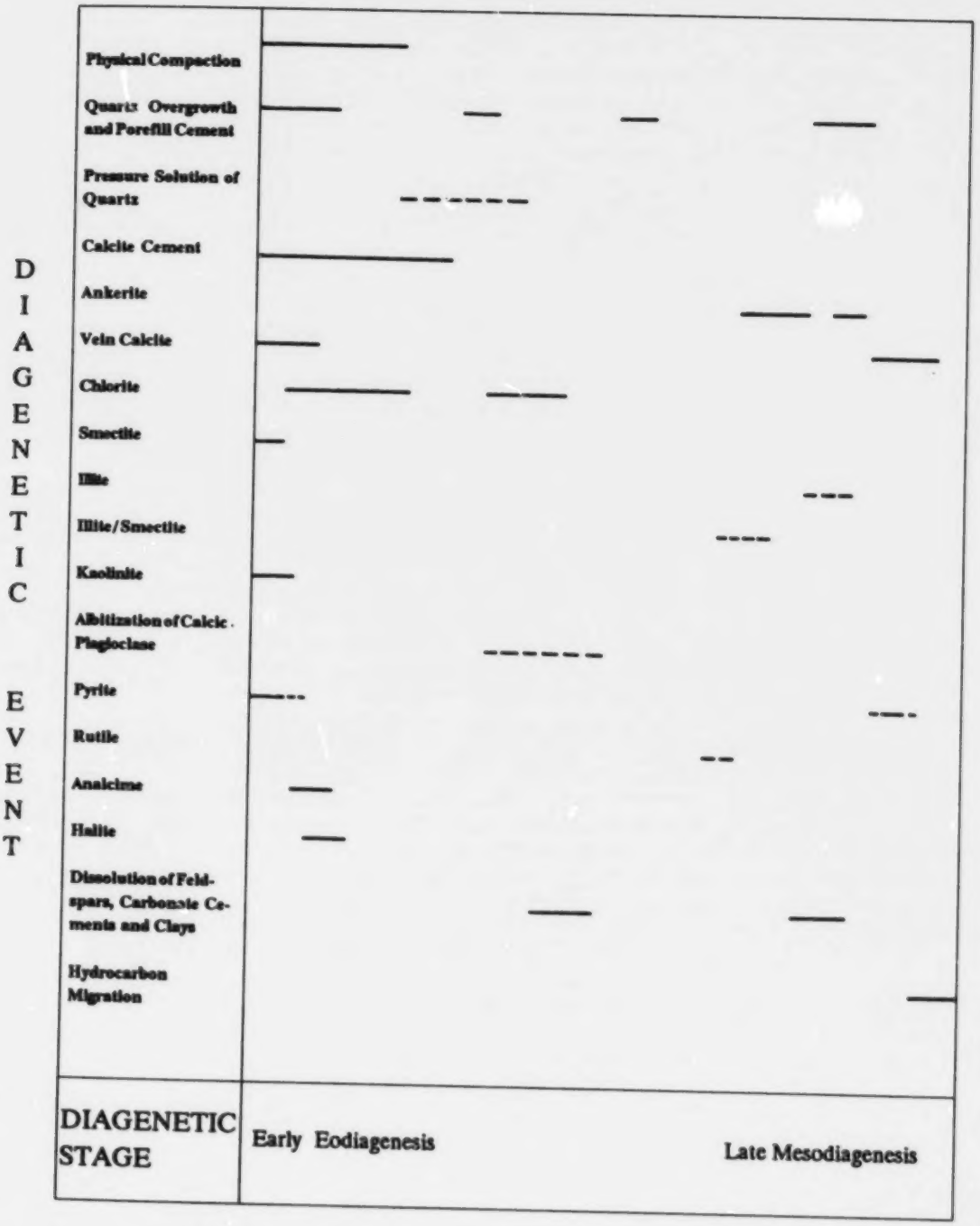



FIGURE 33. Paragenesis of different diagenetic minerals as determined from thin-section petrography and scanning electron microscopy.

surface waters. Carbon isotopes of ankerite suggest a derivation mainly from methanogenesis and solution of earlier calcite cements.

Albitization of feldspars has been studied by thin-section petrography, microprobe, X-ray diffraction (XRD), and X-ray florescence (XRF) analyses. Albite or $Na_2O$ content of the sandstones obtained by bulk XRD and XRF analyses do not show any trend with increasing burial depth, which is probably a result of provenance variation. Thin-section petrography suggests that albitization has taken place. Microprobe analyses of the feldspars in Irving Chevron Hillsborough - 1 at a depth of 1910 m show a composition $Ab_{92.76}$ $An_{6.83}$ $Or_{0.59}$ and at a depth of 2364 m a composition of $Ab_{98.5}$ $An_{1.06}$ $Or_{0.59}$. Assuming that the initial composition of the feldspars was similar to feldspars from plutons in the Caledonia Uplift, a mass balance calculation suggests that up to 3 pore volumes of Na-rich water are required to attain the observed albitization.

The burial history of the Albert Formation has been modelled from available age data (Utting 1987) and from stratigraphic thicknesses of formations in wells of the Subbasin. Maximum burial depth of the Albert Formation has been determined from linear regression of vitrinite reflectances to a surface value of 0.3 Ro%. Maximum burial depth of the Albert Formation varies up to 6.5 km. From 2.2 to 4.5 km of overburden erosion is suggested.

A time-temperature model has been advanced for the Albert Formation. The model suggests that the ankerite cements formed 7 million years after burial (355 to 348 M.Y.B.P.) at a paleoburial depth of about 3 km and a temperature of 125°C (gradient 35°C and surface temperature 20°C). Similarly, calcite cements were formed at a temperature of up to 75°C and within 3 million years of burial.

Petrcleum geochemistry of the Albert Formation has been examined by Rock-Eval pyrolysis, fluorescence and reflected light petrography, gas chromatography (GC) of the gasoline range ($C_5$ to $C_8$) and $C_{15+}$ saturated hydrocarbons, hydrous pyrolysis (280°C and 330°C) and sterane and terpane biomarker analyses by gas chromatography and mass spectrometry. Gasoline range analyses of the pyrolysate, oil, and soluble organic sediment extracts suggest derivation from mixed organic matter (type I and III) with an absence of biodegradation or water washing. Gas chromatography of the oils show the presence of a complete envelope of saturated hydrocarbons suggesting that the oils are mature. Biomarker analyses imply that the oils are devoid of tricyclic terpanes and show low abundance of $C_{27}$ steranes as compared to $C_{28}$ and $C_{29}$ steranes and a low ratio of rearranged steranes. Pristane/phytane ratios of the oils are also similar to the soluble organic sediment extracts derived from cutting at Irving Chevron Stoney Creek - 1 and

Irving Chevron Hillsborough - 1. This suggests that the Albert oils are generated mainly from higher plants with a minor contribution from algae. The time-temperature model also suggests that the hydrocarbons started generation at a paleoburial depth of 1500 m at 75°C, and 352 million years before present. Because of the short burial time, only a low percentage of the available organic matter was converted to hydrocarbons.

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# GEOLOGY AND GENESIS OF THE MOUNT COSTIGAN Pb-Zn DEPOSIT, VICTORIA COUNTY, NEW BRUNSWICK (MDA)*

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Brecciated rocks are the primary sulphide host for the Mount Costigan Pb-Zn deposit, 40 km east of Plaster Rock, New Brunswick. The breccia occurs in two main types: 1) a polymictic allochthonous breccia with evidence of significant fragment rotation and dislocation; and 2) a monomictic autochthonous crackle breccia that shows evidence of only minor movement.

Mineralization occurs as fine- to coarse-grained sphalerite and galena (up to 20% Pb+Zn) and pyrite, with minor chalcopyrite and fluorite. Sulphides occur in four main styles: 1) filling of fractures and between breccia fragments; 2) replacement of pumice fragments and of compositional banding in crystal tuff; 3) pods and veinlets in crystal tuff breccia fragments and/or matrix; 4) fine-grained disseminations in breccia fragments and matrix.

Construction of multiple cross-sections using drill information shows the local stratigraphic sequence to be generally continuous beneath the autochthonous breccia zones. This indicates the breccia to be more stratiform than discordant.

The mineralization is interpreted to be a base-metal variety of an epithermal deposit. The brecciated host rocks formed during the initial stage, whereas sulphide deposition occurred during the mature, later stages of the epithermal system.

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Des brèches renferment les sulfures du dépôt à Pb/Zn du mont Costigan, 40 km à l'est de Plaster Rock, N.-B. La brèche est de deux type principaux: 1) polymictique, allochthone avec rotation et dislocation evidentes des fragments, et 2) une brèche monomictique, autochthone, à fissures qui n'indiquent qu'un mouvement faible.

La minéralisation est en sphalerite et galène à grain fin à gros (jusqu'à 20% Pb+Zn) et pyrite, avec un peu de chalcopyrite et de fluorite. Les sulfures sont en quatre formats principaux: 1) remplissage de fractures et entre fragments de brèche; 2) remplacement de fragments à pumice et de rubanements à composition des tufs à cristaux; 3) petit amas et veinules dans les fragments de tufs brèchique à cristaux et/ou dans la pâte; 4) dissemination à grain fin dans les fragments de brèche et la pâte.

Les sections verticales, multiples, d'après les données des forages, indiquent que la séquence stratigraphique locale est, d'une façon génerale, continue en dessous des zones de brèche autochtone. Ceci indique que la brèche est plus stratiforme que discordante.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

La minéralisation est prise comme une variété, en métaux à base, d'un dépôt épithermal. L'hôte, une roche brèchiforme, a été mise enplace à l'étage initial, tandis que la déposition des sulfures a pris place plus tard pendant les stages mures du système epithermal.

The Mount Costigan Pb-Zn deposit is located about 40 km east of Plaster Rock, New Brunswick (Figure 34) within the Early Devonian Costigan Mountain Formation, in the Matapédia Cover Sequence (formerly the Chaleur Bay synclinorium) (Fyffe and Fricker 1987). It occurs about 250 m east of the summit of Mount Costigan within a series of brecciated and unbrecciated crystal and lapilli tuff, rhyolite and minor siltstone, which is exposed in six trenches (North, South, East, West, Southwest and Central). The deposit is underlain to the east by massive and pillowed basalt and a series of intercalated siltstone, conglomerate, crystal and lapilli tuff. To the west, it is overlain by poorly bedded, locally brecciated lapilli tuff, massive to flow-banded rhyolite and a similar sequence of intercalated siltstone and tuff. Further west on the property, the Mount Costigan Formation is overlain by shales and greywackes that are correlated with the Wapske Formation (St. Peter 1978).

The most significant feature of the deposit is the brecciated rocks, which also serve as the primary sulphide host in the Central Trench. Thin-section and field studies indicate that these rocks consist of angular to subangular blocks of massive and banded crystal tuff, massive to spherulitic to flow-banded rhyolite, and minor lapilli tuff. The breccia occurs in two main types: 1) a polymictic allochthonous breccia exposed in the Central Trench (banded crystal tuff and flow-banded rhyolite fragments dominating) with evidence of significant fragment rotation and dislocation. The original matrix has been replaced by fine-grained quartz and feldspar; and 2) a monomictic crackle breccia exposed in the North Trench. This breccia shows evidence of only minor movement as many of the fragments clearly show matching walls, and is interpreted to be autochthonous.

The broadly circular surface plan of the breccia at Mt. Costigan led previous investigators (Crevier 1983, 1984; Fyffe and Pronk 1985) to suggest that it was a breccia pipe associated with the emplacement of the Redstone Mountain Granite. However, the present study has shown subsurface breccia zones can be separated by as much as 70 metres of unbrecciated crystal tuff, lapilli tuff rhyolite, and siltstone. Furthermore, construction of multiple cross-sections using drill information shows the local stratigraphic sequence to be generally continuous beneath the autochthonous breccia zones (Figure 35). These observations indicate the breccia to be more stratiform than discordant, which would contradict a breccia-pipe origin. The very angular nature of the fragments in the allochthonous

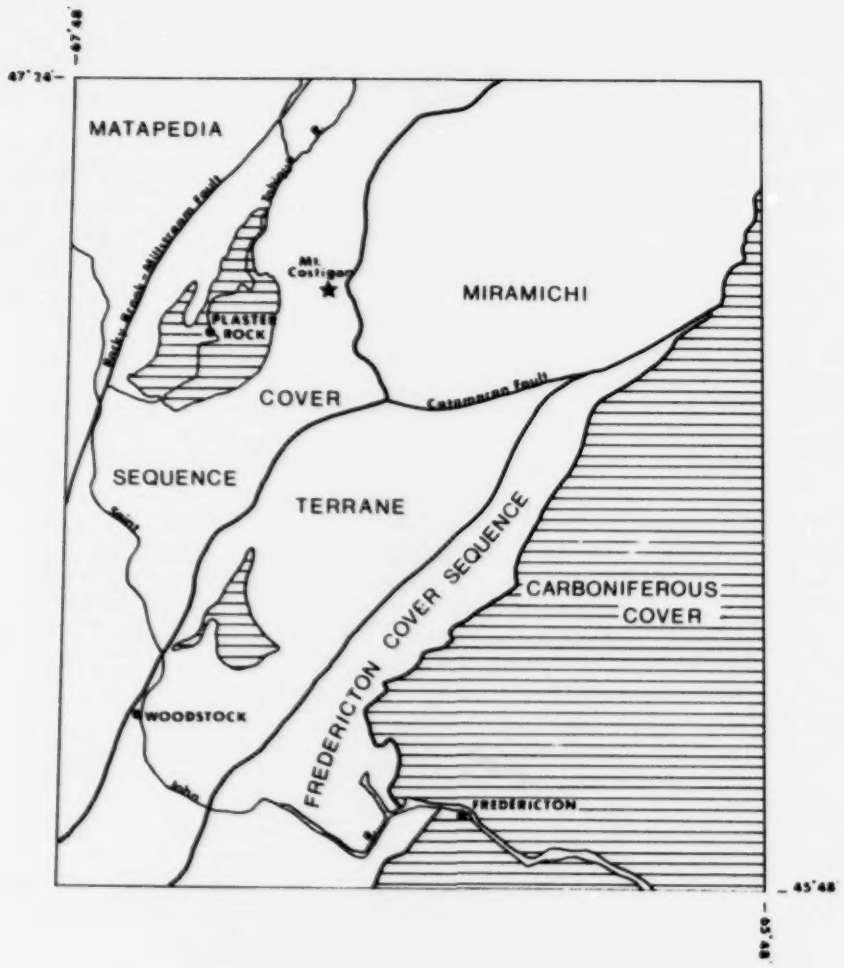


FIGURE 34. Location map showing Mount Costigan study area with respect to tectonic zones of New Brunswick.

breccias, along with the predominance of crystal tuff and rhyolite as fragment lithologies, suggests these rocks are the result of explosive volcanic activity or represent a lag deposit located on the flanks of a small rhyolite dome.

Mineralization occurs as fine- to coarse-grained sphalerite and galena (up to 20% Pb+Zn) and pyrite, with minor chalcopyrite and fluorite. Silver (1.5 to 28.0 g/t) is most closely associated with the galena. While trace and disseminated mineralization occurs over the extent of the breccia zone exposed in the Central Trench, distinct areas of notably greater sulphide abundances have been grouped into regions of medium and high sulphide concentration. Sulphide textures in these areas occur in four main styles: 1) filling of fractures and between breccia fragments; 2) replacement of pumice fragments in

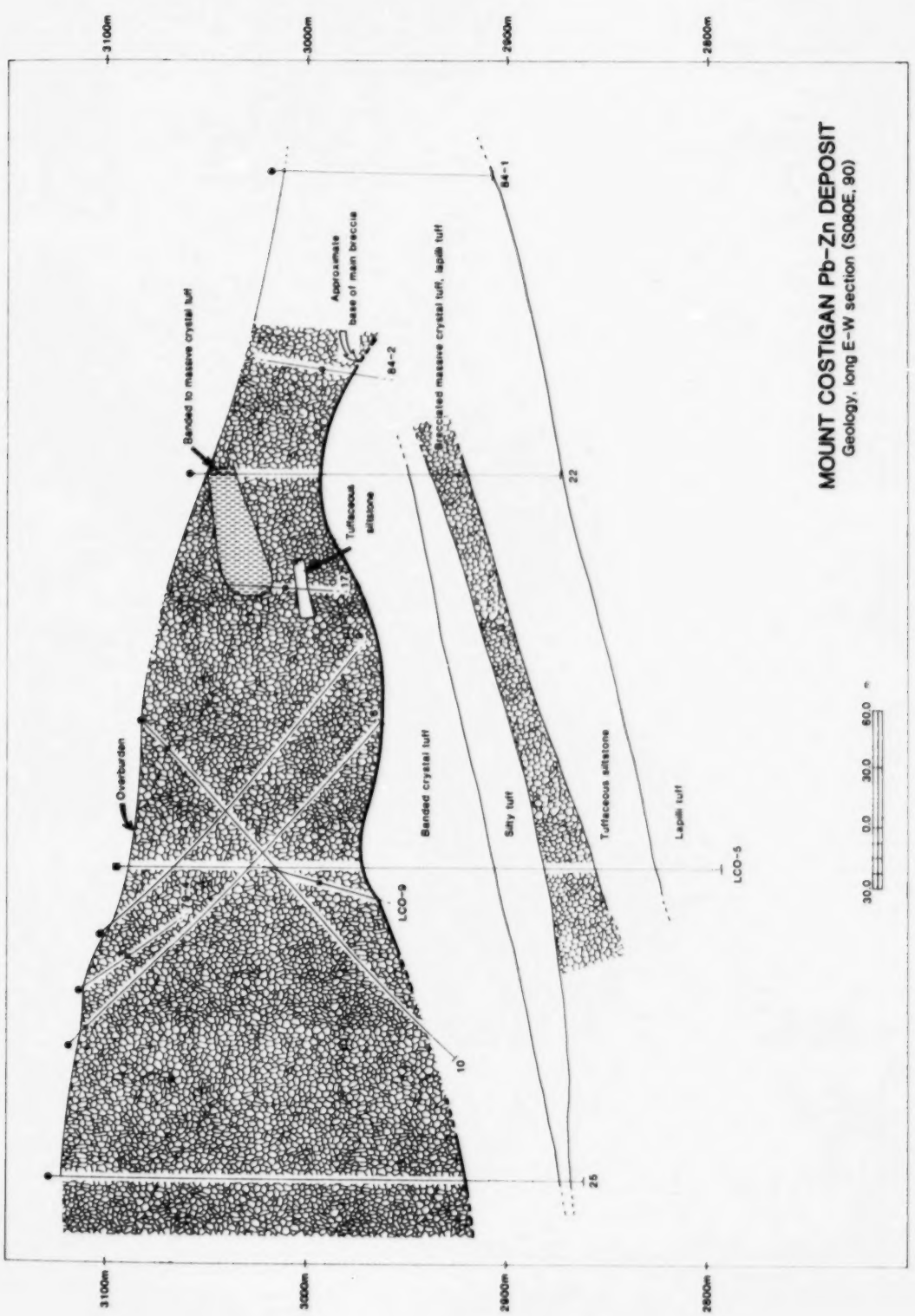


FIGURE 35. Geological cross-section, Mount Costigan Pb-Zn Deposit.

rhyolite and crystal tuff and replacement of compositional banding in crystal tuff; 3) pods and veinlets in crystal tuff breccia fragments and/or matrix; 4) fine-grained disseminations in breccia fragments and matrix.

Mineralization at Mount Costigan has occurred in at least two phases. The earliest phase occurred prior to the development of the breccia and is represented by disseminated sulphide mineralization in unbrecciated blocks of crystal tuff within and outside of the breccia zone. The second, main, mineralizing phase occurred after the brecciation and is represented by open-space, fracture filling, and replacement sulphides.

Successive zones of mineralized breccia, separated by poorly mineralized to barren, unbrecciated zones, have been identified within the stratigraphy. This suggests mineralizing fluids moved along faults and fractures cutting the less permeable unbrecciated zones, and then into the breccia where the porosity was greater. The fluids were then controlled by the distribution and permeability of the breccia.

Epithermal systems commonly develop in the waning stages of volcanic activity (Laznicka 1985), following a phase of explosive volcanism. The Mount Costigan deposit is interpreted to be a base-metal variety of an epithermal system. The brecciated host rocks formed during the initial phase of the epithermal system. Sulphide deposition occurred during the mature, later stages of the epithermal system.

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# RESIDUAL TOTAL FIELD AND VERTICAL GRADIENT COMPOSITE MAPS OVER THE MIRAMICHI TECTONIC ZONE, NEW BRUNSWICK (MDA)*

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In 1984, 1985, 1986, and 1988, a total of 55 809 km of helicopter aeromagnetic total field/gradiometer/VLF survey lines were flown over the Miramichi tectonic zone under contract to the Geological Survey of Canada as a contribution to the Canada-New Brunswick MDA.

For all four surveys, the flight line separation was 300 m at a mean elevation clearance of 150 m. The line direction over the northern half of the Miramichi volcanic-sedimentary belt was north-south, while that over the southern half was east-west.

Final survey products were in the form of digital data and 1:20 000 aeromagnetic total field and gradiometer contour maps. Total field and gradiometer colour interval maps and residual total field and gradiometer colour interval maps were produced at 1:50 000 scale in 1984-85 and 1986-88, respectively. VLF-EM data, using stations at Cutler, Maine and Annapolis, Maryland, were presented in the form of profiles.

The magnetic total field data are primarily used for identifying and extending geological units under sedimentary cover, whereas the vertical gradient is effective for outlining vertical contacts between rock units with contrasting magnetizations. The VLF-EM anomalies are often associated with contrasts in conductivity between rock units in addition to cultural features.

The Canada-New Brunswick-MDA-funded gradiometer surveys have made a significant contribution to the detailed mapping of the Miramichi zone.

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En 1984, 1985, 1986, et 1988 un total de 55 809 km de lignes ont été survolées en helicoptère au-dessus la zone tectonique Miramichi pour des levées aéromagnétique à champ total, gradiomètrique, et VLF, sous un contrat avec la Commission Géologique du Canada et faisant partie de l'Entente de Développement Minéral Canada/Nouveau-Brunswick.

Dans les quatre années la séparation entre les lignes de vol était 300 m et l'élévation moyenne de l'instrument était 150 m. Pour la moitié septentrionale de la ceinture volcano-sédimentaire les lignes étaient nord-sud, et pour la moitié sud elles étaient est-ouest.

Les résultats finals étaient comme données digitales et comme cartes à contours à 1:20 000 du champ aéromagnétique total et gradiométrique. Des cartes à champ total et gradiométrique à intervalles en couleurs, et des cartes à champ total résiduel et gradiométriques à intervalles en couleur ont été faites à 1:50,000 en 1984-85 et 1986-88, respectivement. Les données VLF-EM, utilisant les stations à Cutler, Maine et Annapolis, Maryland, ont été présentées en profils.

Les données du champ magnétique total sont utilisées surtout pour l'identification et la prolongation d'unités géologique sous une couverture sédimentaire, tandis que le gradient vertical est efficace dans la délimitation des contacts verticaux entre des unités de roches à caractère magnétique contrastant. Les anomalies VLF-EM sont souvent associées avec des contrastes dans la conductivité entre les unités de roches, en plus des activités humaines.

Les levées gradiométriques payées par des fonds Canada/Nouveau Brunswick ont porté une contribution notable à la cartographie détaillée de la zone Miramichi.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

# QUATERNARY GEOLOGY AND TILL GEOCHEMISTRY OVER THE MIRAMICHI ZONE: AN UPDATE ON PUBLICATION (MDA)*

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The results of the regional till geochemistry project have been released in the form of Open Files. The objective of the project was to provide a database for the geochemistry of the regional till sheet that covers the Miramichi Zone and adjacent areas. Regional Open Files cover the Northern, Central, and Southern portions of the Miramichi Zone (Lamothe 1988a; 1988b; in press), an area extending from the international border with Maine to the Baie des Chaleurs coastal area. Each Open File includes a 1:250 000-scale sample location map and 1:50 000-scale individual location maps. These maps could not be provided in the partial regional Open Files. Two types of geochemical maps will be published: 1:250 000-scale contour maps with dots and 1:500 000-scale "laserdots" maps. These maps include logarithmic-scale dots that clearly highlight the anomalous zones. Also, overlapping samples in a given area can be individually observed by the use of a white inset around the individual dots. The reports include the original database: e.g., tables of the geochemical results for the clay and the clay-plus-silt fraction of the till samples, tables of averaged values where more than one analysis was available, and tables showing lists of duplicate analyses. Particular attention was given to the reproducibility of the data. Since 20 to 30% of the samples were analysed more than once, the values at each site were averaged out so that the geochemical maps should reflect the true geochemical relief of the area. The data will be made available in subsets on diskettes for each 1:250 000 map area.

The sequence of glacial events can be deduced from the study of erosional features (mostly striae). Drilling, trenching, and detailed analysis of exposures suggest the presence of more than one till. A radiocarbon date on an intertill organic deposit at Hayesville has provided evidence for active ice in the central Miramichi Highlands at 11 000 years BP. These results justify a revision of the sequence of Quaternary events in this part of the Province. They also have consequences for the interpretation of till-geochemistry data and exploration (Seaman, in press).

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Les résultats du projet de recherche sur la géochimie du till régional sont publiés sous forme de Dossiers publics. Le format des publications qui a été adopté est décrit plus bas. L'objectif de ce projet est de produire une banque de données

illustrant la géochimie du till régional qui recouvre les roches de la Zone de Miramichi et de ses environs. Les dossiers publics régionaux couvrent les parties méridionale, centrale et septentrionale de la Zone de Miramichi, de la frontière internationale du Maine à la région côtière de la baie des Chaleurs. Chaque dossier public inclut une carte de localisation des échantillons à l'échelle de 1:250 000 ainsi que des cartes de localisation individuelles au 1:50 000. Ces cartes n'ont pu être produites pour les dossiers publics partiels. Deux types de cartes géochimiques sont construites: des cartes au 250 000 ème avec contours et cercles, et des cartes au 50 000 éme, avec cercles proportionels ('laserdots"). La taille des cercles varie de façon logarithmique avec la valeur mesurée au site ce qui permet de faire ressortir plus clairement les zones anomalies. De plus, le lecteur peut observer des points d'échantillonage de valeur moins élevée localisés sous ou près d'échantillons anomalaux. Les rapports présentent la banque de données originales, i.e. les tableaux des résultats de l'analyse géochimique de la fraction argileuse et de la fraction argileuse et silteuse des échantillons de till, les tableaux des valeurs moyennes lorsque plus d'une analyse a été effectuée au même site, et des tableaux montrant la liste des analyses en duplicata. L'étude de la reproductibilité des données a fait l'objet d'une attention particulière. Ainsi, les cartes géochimiques sont produites à partir des valeurs moyennes obtenues à chaque site, puisque de 20 à 30% des échantillons ont été analysés plus d'une fois. Les cartes géochimiques devraient donc refléter le relief géochimique régional. L'ensemble des résultats sera disponible sous la forme de produits individuels de telle façon que les disquettes et les cartes au 250 000 ème puissent être achetées séparément.

L'interprétation de la géochimie du till de surface doit tenir compte 1) de la séquence des événements d'érosion glaciaire, déduite en grande partie des marques d'érosion, surtout des stries, 2) de l'existence de deux à trois tills mis en place durant la dernière glaciation et 3) de la présence de glace active dans la partie centrale de la Zone de Miramichi autour de 11 000 années AP. L'analyse détaillée des sédiments prévelés lors des campagnes de forages et de tranchées, ainsi que l'étude de coupes naturelles permettent d'élaborer un cadre stratigraphique de référence pour la séquence de sédiments du Pléistocène. Ces données, ainsi que l'analyse géomorphologique de surface, suggèrent une révision de la séquence des événements géologiques ayant eu lieu au cours du Quaternaire dans cette partie de la province.

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# PLATINUM-GROUP-ELEMENT MINERALIZATION IN THE MECHANIC SETTLEMENT INTRUSION, KINGS COUNTY, NEW BRUNSWICK (MDA)*

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The Mechanic Settlement intrusion is a lenticular-shaped, layered intrusion covering an area of approximately 8 $km^2$ near the small community of Mechanic Settlement. The intrusion consists of peridotite, olivine pyroxenite, troctolite, olivine gabbro, olivine gabbronorite, gabbronorite, anorthosite, and gabbro. At the exposed level of the intrusion, there are at least three cyclic units, each beginning with peridotite. Mineral compositional variations reflect cryptic patterns and correspond to normal fractionation trends in each cyclic unit. Platinum-group-element mineralization occurs in two zones with PGE grades up to 2.6 g/t. Platinum-group minerals identified to date are vysotskite, merenskyite, michenerite, sperrylite, stillwaterite, and hollingworthite. Cu to Ni and Pt to Pd ratios, and chondrite-normalized plots of PGE concentrations of the Mechanic Settlement sulphides are similar to flood basalt-related ores. Sulphur-isotope ratios, ranging from +3.8 to +6.3, and Se/S ratios in the Mechanic Settlement sulphides, are similar to the mantle values.

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L'intrusion Mechanic Settlement est de forme lenticulaire d'une superficie d'environ 8 $km^2$ et proche de la petite communité de Mechanic Settlement. L'intrusion est de péridotite, pyroxènite à olivine, troctolite, gabbro à olivine, gabbro/norite à olivine, gabbro/norite, anorthosite, et gabbro. Au niveau où l'intrusion est visible il y a au moins trois unités cycliques, chacune commençant avec péridotite. Les variations de la composition des minéraux sont un reflet de patrons cachés et de tendances normales de fractionation dans chaque unité du cycle. Une minéralisation du groupe d'éléments de platine se trouve dans deux zones avec des teneurs à 2.6 g/t. Les minéraux de ce groupe identifiés jusqu'à date sont vysotskite, merenskyite, michenerite, sperrylite, stillwaterite, et hollingworthite. Les proportions de Cu à Ni et Pt à Pd, et les mises en graphique à chondrite normalisées du PGE des sulfures à Mechanic Settlement sont semblables à celles de minerais apparentés aux minerais apparentés aux épanchements énormes de basalte. Des rapports des isotope à sulfure de (+) 3.8 à (+) 6.3 et de Se/S des sulfures de Mechanic Settlement sont semblable à ceux du manteau.

The Mechanic Settlement intrusion outcrops over an area of approximately 8 $km^2$ near the community of Mechanic Settlement. The lenticular intrusion appears to be grossly conformable with the surrounding volcanic rocks of the Coldbrook Group (Paktunc 1989). The relationship with the granitic rocks exposed near

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

the southwestern end of the intrusion is uncertain because of the poor exposure.

The intrusion is layered and consists of peridotite (olivine-chromite cumulate), olivine pyroxenite (olivine-bronzite-augite cumulate), troctolite (olivine-plagioclase cumulate), olivine gabbro (olivine-plagioclase cumulate), olivine gabbronorite (olivine-plagioclase-bronzite-augite cumulate), gabbronorite (bronzite-augite-plagioclase cumulate), anorthosite (plagioclase cumulate), and gabbro (plagioclase-augite cumulate). Correlation of the rock types from one outcrop to another is difficult due to poor exposure and rarity of marker layers. At the exposed level of the intrusion, there are at least three cyclic units, each beginning with peridotite. Olivine ranges in composition from Fo78 to Fo84 and plagioclase from An62 to An89 in the peridotitic rocks, and from Fo72 to Fo80 and plagioclase from An60 to An89 in the olivine-bearing mafic rocks. Variations in the compositions of orthopyroxene and clinopyroxene are within Wo1-4En77-83Fs14-19 and Wo41-46En47-52Fs6-9 for the peridotitic rocks, Wo2-4En52-79Fs17-45 and Wo39-47En36-48Fs7-25 for the noritic rocks. These compositional variations reflect cryptic patterns and correspond to normal fractionation trends in each cyclic unit.

Platinum-group-element (PGE) mineralization, discovered following detailed mapping of the intrusion, occurs in two zones. Zone I, characterized by the presence of interstitial sulphides up to 5%, occurs in the feldspathic peridotite of the lowermost cyclic unit. Typical PGE grades obtained from this zone are about 2 g/t. Zone II occurs in the olivine gabbro-norite of the uppermost cyclic unit. Coarse-grained blebby sulphides forming up to 8% of the rock are associated with the pegmatitic portions rich in hydrous phases. Combined PGE concentration of this zone is 2.6 g/t. The main sulphides are pyrrhotite, pentlandite, and chalcopyrite. Platinum-group elements occur as discrete platinum-group minerals. These are vysotskite [(Pd,Ni)S], merenskyite [$(Pd,Pt)(Te,Bi)_2$], michenerite [(Pd,Pt)BiTe], sperrylite [$PtAs_2$], stillwaterite [$Pd_8As_3$], and hollingworthite [(Rh,Pt,Pd)AsS]. Electrum [AuAg] and native gold are the other precious-metal-bearing minerals. Cu/Ni and Pt/Pd ratios, and chondrite-normalized plots of PGE concentrations in the sulphide fraction of the Mechanic Settlement sulphides are similar to those of the flood basalt-related ores. Sulphur-isotope ratios range from +3.8 to +6.3 per mil in the Mechanic Settlement sulphides. Se/S ratios are similar to the mantle values.

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# CYCLIC, BIMODAL VOLCANISM IN A CONTINENTAL VOLCANIC ZONE, CHARLOTTE COUNTY, NEW BRUNSWICK (MDA)*

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Siluro-Devonian bimodal volcanic and intercalated sedimentary rocks occur in four cycles in the northern extension of the coastal volcanic belt. The mafic and felsic units occur as both lava flow and pyroclastic units including welded and nonwelded air-fall, surge, and pyroclastic flow deposits. The sedimentary rocks are typical of intertidal environments with rapid sedimentation rates. Reworked volcanic rocks are rare. Felsic rocks are subalkaline but have high Y, Nb, and Zr abundances comparable to alkalic rhyolites. Mafic units are tholeiitic and plot along a single trend with Y, Nb, Zr, and $SiO_2$ decreasing and Ni and Cr increasing upward in the section. The trends can be explained by replenishment and/or assimilation fractional crystallization. The most likely geological setting is a volcanic plain lacking large calderas located within a continental rift.

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Les roches sédimentaires intercalées et volcaniques bimodales du Siluro-devonien se présentent en quatre cycles dans le prolongement nord de la ceinture volcanique côtière. Les unités mafiques et felsiques se présentent à la fois sous forme de coulées de lave et d'unités pyroclastiques qui comprennent des chutes de cendres fusionnées et non fusionnées, des avancées de lave et des coulées pyroclastiques. Les roches sédimentaires sont typiques des environnements intertidaux avec des taux des sédimentation rapides. Les roches volcaniques remaniées sont rares. Les roches felsiques sont subalcalines, mais contiennent des taux de Y, Nb et Zr élevés, comparables aux rhyolites alcaliques. Les unités mafiques sont tholéiitiques et présentent un tracé unique avec des taux de Y, Nb, Zr et $SiO_2$ décroissants et des taux de Ni et Cr croissants dans la partie supérieure de la section. Le contexte géologique le plus plausible est une plaine volcanique ne comportant pas de caldeira importantes, qui est située sur une faille continentale.

The coastal volcanic belt of New Brunswick and the northeastern United States comprises a bimodal sequence of marine to subaerial Silurian and Early Devonian volcanic rocks. The northern extension of this belt, exposed along the coast of Passamaquoddy Bay, southwestern New Brunswick, has been investigated in detail. The physical and chemical volcanology has been used to interpret the tectonic setting. The belt comprises about 180 $km^2$ of intercalated littoral to subaerial bimodal volcanic and sedimentary rocks, forming a 4 km-thick

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

section that is intruded by the Saint George Batholith and overlain uncomformably by the coarse alluvial deposits of the Late Devonian Perry Formation.

Bimodal, mafic-felsic volcanism occurs in four cycles. Mafic volcanism accompanies felsic volcanism in each cycle with felsic units being most voluminous in all but the final cycle, where mafic flows dominate over small felsic intrusions. Sedimentary rocks are interbedded with the volcanic rocks throughout the sequence but predominate in the final cycle, which likely represents waning stages of volcanism. Hawaiian, Strombolian, Plinian, and Vulcanian eruptive systems are represented. The mafic units form flow, scoria cone, phreatomagmatic tuff cone, and peperitic breccia deposits. The felsic units were emplaced as welded and nonwelded air fall, ash cloud, ground and base surge, and pyroclastic flow deposits, as well as lava flows and domes. Facies analysis and unit morphology indicates eruptions from multiple small volcanic centres. The basaltic flows, however, consistently flowed from the N and NE to the S suggesting eruption from a single rift system. The sedimentary rocks are mainly red siltstone and sandstone with plane and cross-bedding and lamination, mudcracks, raindrop imprints, vertical to inclined burrows and a faunal fossil assemblage typical of intertidal conditions. Reworked volcanic rocks are rare. All sedimentary units contain well-preserved cuspate and scoriaceous shards, indicating deposition in a low-energy environment with rapid sedimentation rates.

The extrusive volcanic rocks display a compositional gap between 58 and 69% $SiO_2$. Major-element plots of the felsic rocks suggest they are calc-alkalic, but the abundances of the immobile elements Y, Nb, and Zr, are comparable to those of alkalic to peralkalic rhyolites. REE patterns for the felsic rocks suggest one main source. The mafic rocks are tholeiitic and both mafic and felsic rocks have a within-plate tectonic affinity. Mafic units from cycles one, two, and four (east) plot as distinct groups for most immobile trace elements but lie along a single trend with incompatible elements (Y, Nb, Zr) and $SiO_2$ decreasing upward in the section, and compatible elements (Ni, Cr) increasing upward. Mafic rocks from cycle three plot at either end and slightly off this geochemical trend. The trends can be explained by replenishment fractional crystallization or assimilation fractional crystallization. Cycle four consists of two distinct groups (east and west), with different REE slopes, trace-element abundances, and geographic distribution.

Considering the constraints based on 1) composition of the volcanic rocks, 2) nature of volcanic cycles, 3) thickness of the sequence and the subsidence history, 4) rates of sedimentation, 5) facies relationships, and 6) synvolcanic structures, the most likely setting is a volcanic plain lacking large calderas located within a continental rift.

# UTILIZATION OF LANDSAT TM, AIRBORNE SAR, AND GEOPHYSICAL DATA IN ENHANCED IMAGE ANALYSIS OF GEOLOGIC STRUCTURES, RESTIGOUCHE AND GLOUCESTER COUNTIES, NEW BRUNSWICK (MDA)*

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Several types of spatial data were used to investigate and characterize the regional structure for an area northeast of Bathurst, New Brunswick: LANDSAT TM (Thematic Mapper) and airborne SAR (synthetic aperture radar) imagery, radiometric and magnetic surveys. New techniques for concurrent analysis of multiple digital data sets are being developed. Two methods, principal component analysis (PCA) and Minimum/maximum autocorrelation factor analysis (MAF) are applied. The results were used to produce enhanced digital images that were compared to known geologic lineaments in the area.

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Plusieurs genres de données spatiales ont été utilisés à connaitre et à caractériser la tectonique régionale dans une région au nord-est de Bathurst, Nouveau Brunswick: LANDSAT TM (cartographie à thème) et images SAR (radar à aperture sythéthique), levées radiométriques et magnétique. Des techniques nouvelles pour l'analyse en parallel de groupes multiples de données digitales sont en train à être developpées. Deux méthodes, l'analyse du component principal (ACP) et l'analyse autocorrélation minimum/maximum (AMM), sont appliquées. Les résultats ont servis à produire des images digitales améliorées qui ont été comparées avec des linéations géologiques connues dans la région.

The study area in northeastern New Brunswick (Figure 36) has been the focus of several geoscientific investigations under the Canada-New Brunswick MDA. As a refinement of a comprehensive regional integration project (Watson and Rencz 1988; Watson et al. 1989), new techniques for concurrent analysis of multiple data sets are being developed.

The structure of the study area is dominated by the Rocky Brook-Millstream fault system, a northeast-trending transcurrent dextral shear zone. Previous studies have demonstrated that geological structures of certain preferred orientations are spatially correlated with known mineral occurrences (Rencz and Watson 1986).

Several types of spatial data were used to investigate and characterize the regional structure: LANDSAT TM (Thematic Mapper) and airborne SAR (synthetic aperture radar) imagery,

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

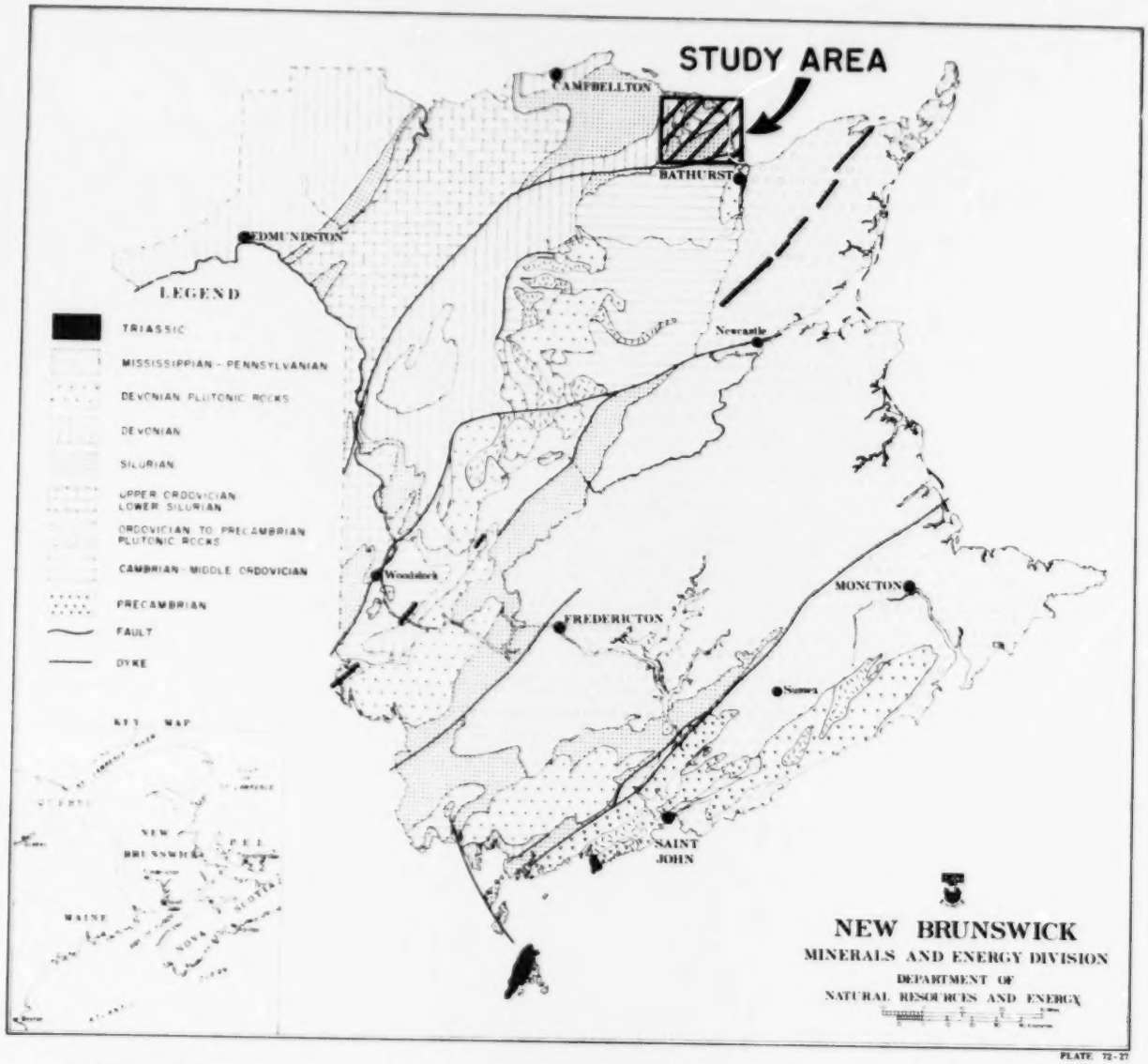


FIGURE 36. Location map of GIS study area in northeastern New Brunswick with respect to tectonic zones.

radiometric and magnetic surveys. Each of these data sets was evaluated separately and then co-registered to a common geographic base using a microcomputer-based image analysis system. From these data sets, there was a total of 18 unique layers of information (6 bands of TM data, 2 bands of SAR, 10 radiometric, magnetic, and VLF channels).

When separate plots of these layers are produced, some appear quite similar in depiction of main geographic features, such as major rivers, highways, towns, broad geological divisions, etc., although each plot portrays the information

differently depending upon the configuration, resolution, and sensitivity of the detectors and the particular property being measured. The overall similarity leads to the questions: "Can the number of images be reduced to one or several that contain most of the important information in the original multi-layer sets?" and "Is there a way to utilize concurrently the best information from each of these data layers to produce an enhanced digital representation of the study area which may then be used as a superior base product in structural or lineament analysis?". It is natural to seek ways of rearranging or summarizing the data with as little loss of information as possible. The approach to the problem depends entirely on how we define the "information".

Two methods, principal component analysis (PCA) and Minimum/maximum autocorrelation factor analysis (MAF) are applied. While the variance is the "information" in PCA, the spatial autocorrelation is the "information" in MAF. Therefore, PCA uses the sample covariance matrix based on the sample covariances between samples, whereas MAF explores the sample covariance matrix quotient based on the spatial autocovariance between pixels. The two analyses tackle two different problems and one cannot be "better than" the other in general. They are complementary to each other.

Both PCA and MAF provide enhancements that can be used as a starting point for further image analysis. The data were analysed to enhance linear patterns. This was done using high pass filtering algorithms and a terrain analysis package. The results were used to produce images that were compared to known geologic lineaments in the area.

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# GEOLOGICAL, GEOCHEMICAL, AND ISOTOPIC STUDIES OF GRANITIC ROCKS IN NEW BRUNSWICK (MDA)*

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K-Ar and Rb-Sr muscovite and biotite ages obtained from various granitic samples, together with U-Pb ages, indicate that many major intrusive units, previously assigned to the Devonian, are actually Silurian.

New Nd isotopic analyses of 91 granites from New Brunswick outline three basement blocks underlying the northeastern Appalachians. Juvenile sources are indicated for the granites of the Humber+Dunnage and Avalon zones, whereas reworking of older crust (1.1-1.8 Ga) distinct from the Grenville or Avalon was reported in the Gander zone.

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Les ages par K/ar et Rb/Sr sur muscovite et biotite d'un chantillon de granite, et les ages par U/Pb, indiquent que beaucoup d'intrusions majeures, qu'on a prises comme d'age Devonien, sont d'age Silurien.

Des analyses isotopiques a Nd sur 91 granites du Nouveau Brunswick et du Quebec indiquent des sources a predominance juvenile pour les zones Humber, Dunnage, et Avalon. Ces donnees circonscrivent trois blocs du socle (Humber + Dunnage, Gander, et Avalon) et indiquent que les granites des zones Gander, Dunnage, et Humber ont besoin d'un protolith distinct de ceux des types des zones Grenville ou Avalon.

This project has had three major components: (1) geological mapping; (2) a detailed petrographic and geochemical study, including trace elements of economic interest (e.g., Sn, W, Mo, Ta, U, Th, Cu, Pb, Zn, Au, REE), of all Paleozoic granites; and (3) isotopic tracer and geochronological dating studies. Interpretation of previously collected geochemical and petrological data has continued during the past year. In addition, major granite Nd isotopic and geochronological studies have been completed. Details are given below only for work completed during the last year; previously published results are referenced. (1) Geological Mapping: The map area at the northern end of the Central Plutonic Belt described by (Whalen 1987; 1988a) was released as an open file map with marginal notes at 1:50 000 (Whalen 1988b) and will also be published in 1990 as a coloured map at 1:100 000 scale (Whalen, in press). The mapped area of about 2300 km$^2$ is located between 47°00′, 47°28′ latitude and 66°15′, 67°00′ longitude and includes portions of NTS sheets 21 O/1, 2, 7 and 8. (2) Petrological and Geochemical Studies: Preliminary results of

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this work have been reported in Whalen (1986; 1987; 1988a; and 1989). Other publications are in preparation, including a GSC memoir which will contain all the data collected on granites in New Brunswick. (3) Isotopic Studies: Isotopic tracer and geochronological studies on New Brunswick granitic rocks consist of Rb-Sr and K-Ar mineral dating (Whalen and Theriault, in press), Nd isotopic tracer work (Whalen et al., in press; in review) and zircon U-Pb geochronological studies (Bevier and Whalen; in press). Additional work by M.L. Bevier is reported separately in this volume.

K-Ar and Rb-Sr muscovite and biotite isotopic ages were obtained from samples of the North Pole Stream granite suite, the Lost Lake, Juniper Barrens and Nashwaak granites and the Pokiok batholith (Skiff Lake, Hawkshaw, and Allandale phases) in the Gander zone. These ages, together with U-Pb ages, indicate that many major intrusive units previously thought to be of Devonian age, are actually of Silurian age. Contrasts exist between intrusions in their level of intrusion and thermal histories.

New Nd isotopic analyses of 91 granites from New Brunswick and Quebec indicate predominately juvenile sources for Humber, Dunnage and Avalon zones. Reworking of older crust (1.1-1.8 Ga) was important in Gander zone. The isotopic data map three basement blocks (Humber+Dunnage, Gander, and Avalon) and indicate that, contrary to earlier suggestions, Gander, Dunnage, and Humber zone granites require a protolith that is different from Grenville- or Avalon-type material.

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# PART III

## UNIVERSITY OF NEW BRUNSWICK

# REPORT OF ACTIVITY, DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING PROGRAM, UNIVERSITY OF NEW BRUNSWICK

H.W. van de Poll
Chairman of the Department of Geology

## GENERAL

The Department comprises 15 full-time Faculty, 3 Post-doctoral Fellows, 1 Professor Emeritus, 1 Research Associate, 7 Technical Staff, 3 Secretarial Staff, 5 full-time, and 2 non-resident PhD candidates; 10 full-time, 1 part-time, and 2 non-resident MSc students (9 of whom are working on New Brunswick projects), and 57 Undergraduate Students (17 science majors in geology and 40 geological engineers). The Natural Sciences and Engineering Research Council supported the Department's on-going research projects in the amount of $223 842. In addition, four members of faculty (Drs. Spray, Dunn, White, and Williams) were successful in obtaining a major equipment grant from NSERC in April 1989. The sum of $320 000 was awarded for the purchase of a new analytical scanning electron microscope. The new equipment (a JEOL 6400 SEM) will be installed around the end of 1989 and will include both EDS and WDS analytical attachments which will allow the machine to function as a microprobe as well as an SEM. The equipment will be located in the Electron Microscopy Unit and will be accessible to outside users. The Maritime Provinces Higher Education Commission provided $22 155 for research equipment during 1988-89. The three-year Provincial/Federal MDA-funded Heath Steele Mines project ($242 000/ann.) was completed in March of this year. All reports and accompanying maps have been submitted to the Provincial Department of Natural Resources and Energy. Research contracts for varying periods were negotiated, including various projects with the Geological Survey of Canada ($95 330), Energy, Mines and Resources Canada ($5000), Lithoprobe ($25 000/ann, renewable for three years), Shell ($14 000, two-year funding), Brunswick Mining & Smelting ($18 000/ann. for three years), and smaller amounts from the University of New Brunswick Research Fund ($3230), Chevron ($500), AMOCO Canada Petroleum Company Ltd. ($2500), Challenge '89 ($5546), and others.

Five geologists and nine geological engineers graduated from UNB since our last report. This year's graduating class was noted by the BSc honours, Deans of Engineering, and Science listings (six geological engineers and two geologists) and prizes awarded to its members. Geological Engineering undergraduate, Mr. E. Whyte, won the Canadian Institute of Mining Scholarship, whereas Mr. John Robert Currie and Ms. Christine Bovaird were recipients of the Canadian Society of Petroleum Geologists award. Mr. Chris Hawkes won a Canadian Society of Exploration Geophysicists Scholarship and Mr.

Christoph Faig was awarded an undergraduate scholarship in geophysics by AMOCO Canada Petroleum Company Ltd. In addition, Mr. Christopher Hawkes was the GAC/MAC Fredericton '85 Scholarship recipient. Christopher Beaumont-Smith was this year's recipient of the Dr. J.W. Wright Scholarship. The Tractors & Equipment (1962) Ltd. prize in Geology was awarded to Edwin Neil Michael Vandebrand. The Womens' Association of the Mining Industry of Canada Scholarship was awarded to Suzanne LeBlanc.

The S.W. Bachinski Memorial Scholarship, established by family and friends of S.W. Bachinski, was awarded to Mr. John Robert Currie. This new scholarship is awarded on the basis of scholastic attainment.

All of our graduates were employed for the summer. Two persons completed their PhD's and one MSc was awarded during the past year.

Members of the faculty and graduate students published approximately 40 scientific papers and presented approximately 20 papers at various regional, national and/or international meetings.

Dr. Nicholas Susak has returned from his sabbatical leave at Oak Ridge National Laboratory. Dr. J.L. Davies and Mr. R.R. Irrinki of the Department of Natural Resources and Energy, and Mr. G. Kooiman from Mount Pleasant Mine assisted with the instruction of the GEOL 4442, Mineral Resource Utilization, course.

The Department of Geology has taken two major initiatives in support of geological research and mineral development.

1) Chair in Economic Geology
2) Applied GIS (Geographic Information System) research in geoscience.

<u>Chair in Economic Geology</u>

The Chair proposal is focused on the following objectives:

1) to assist in mineral development in New Brunswick and eastern Canada,
2) to maintain and enhance the inter-relationship between those engaged in mineral exploration and production and those at the University having applicable expertise,
3) to enhance the research capability within New Brunswick in fields of applied geology,
4) to assist the University in maintaining its historical capability of educating and training students who are philosophically and intellectually attuned to the process of discovering and developing new mineral resources.

When approved, the Chair will expand a capability at the University of New Brunswick vital to the future of the mining industry. The total amount of money applied for to cover the Chair's activities over a five- to seven-year period is nearly $1 million dollars. We remain hopeful that this amount will be assembled with help from Industry, Government, and the Natural Sciences and Engineering Research Council during the coming year. The Provincial Department of Natural Resources and Energy is very supportive of our Chair application.

Applied GIS research

This application is in support of improved geoscientific data management. The amount of data related to mineral development generated over the years by industry, government and university research is enormous to the extent that the information is increasingly difficult to access and integrate for lack of a modern data management system. Quick efficient, computer-assisted access to earth science files in the public domain is essential for the sustained growth of the mineral industry.

A Geographic Information System that is well suited for the integration of large earth science databases (including satellite imagery, airborne and ground geophysics, water, soil and rock geochemistry, geology, soils vegetation cover topography, etc.), is the locally developed CARIS (Computer Assisted Resources Information System). Database integration has applications in a variety of earth science, constraint driven management decisions including mineral exploration and mining, effluent discharge, forestry, urban development, harbour dredging, and highway planning.

An application for the establishment and operation of a CARIS workstation has been forwarded to the Provincial Department of Commerce and Technology. The aims and objectives of the CARIS station include the following:

1) to assist in the accelerated development of a new technology in geoscientific research that is also of particular benefit to the mineral industry,
2) to assist the mineral industry in developing more efficient mineral exploration and mining applications, methods, techniques, and assessments,
3) improve the capability of geoscientists at government, industry and University levels to process large databases,
4) create earth science software for CARIS,
5) involve undergraduate and graduate students in the development and application of earth science data management techniques.

Geological Engineering

Geological Engineering continues to be a popular program at UNB with approximately 43 undergraduates enrolled in all

years. Nine students graduated from Geological Engineering this year and 19 new students entered the five-year programme at various levels from year one to year three. Almost every student from first year on was employed in geological work over the summer and this in itself is expected to have a positive impact on future enrolment in the program.

This year Dr. B.E. Broster completes the third year of a three-year term as Director of Geological Engineering. He has also been active as one of two Atlantic representatives and Vice-President of the Canadian Quaternary Association (CANQUA), and is now beginning a two-year appointment as President of CANQUA.

Geochemistry

Dr. Susak spent the year on sabbatical leave at the Chemistry Division of Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S.A. conducting spectrophotometric and potentiometric studies of hydrothermal solutions in collaboration with D.A. Palmer and D. Wesolowski of ORNL. Spectrophotometric studies of Cr(VI) were undertaken to determine the stability of chrome-chloride complexes and to investigate the possibility of using chromate as a colorimetric pH indicator in oxidizing-acid solutions. Work was begun to determine the hydrolysis and chloride complex stability constants for Mo(VI) by potentiometric titration. This study (in conjunction with the previous studies of CR(VI) and W(VI) by the staff at ORNL) will provide the first complete determination of high-temperature stability constants of a chemical group and should provide valuable insights in the general behaviour of elements in hydrothermal solutions. Complementary spectrophotometric studies of Mo(VI) complexes will be conducted at UNB. Spectrophotometric determinations of nickel complexing will also be initiated. Work on the hydrothermal solubility of cobalt oxides and sulphides is continuing.

Geophysics

Dr. K.B.S. Burke, in co-operation with the Geophysics Division of the GSC, completed a study of the April 24th, 1988 earthquake at Turtle Creek, about 12 km SW of Moncton, New Brunswick. The earthquake had a magnitude of $m_N$ = 3.6, a focal depth of 3 to 5 km, and was felt over an area of approximately 4900 $km^2$. A focal mechanism study suggested thrust faulting on north- or northwest-trending planes. Magnitude - felt area relationships gave estimates of 3.6 to 3.7, which compares favourably with the instrumentally determined magnitude. This latter result increases the confidence in using the same relationships to determine magnitudes of historical earthquakes in the Moncton region.

Dr. Burke and J. Currie have commenced the inter- pretation

of a marine geophysical survey of the Passamaquoddy Bay region. Maps at a scale of 1:50 000 have been prepared of the total magnetic field, depth to sea bottom, depth to bedrock, thickness of sediments and bedrock features.

Glacial Geology

Dr. Broster's research has focused upon applications of glacial processes and products relative to engineering, environmental and exploration activities. This year research was completed on two studies of glaciogenic soft-sediment deformation in northern British Columbia with Dr. J.J. Clague of the Geological Survey of Canada, Vancouver. Research on neotectonics at Saint John, New Brunswick, with Dr. Burke was also completed.

New projects have begun in New Brunswick with A.A. Seaman of DNRE on glacial thrusting of weathered granites and with Dr. Clague on crevasse-like structures in northern British Columbia.

Mineral Deposits

Economic geology activity continued to be focused mainly on Appalachian mineral deposits with an emphasis on massive sulphides.

Dr. A.L. McAllister and Dr. H.H. Hassan have now completed their research project on the uranium potential of granitic plutons in the central Miramichi Highlands. Integrated geological, geochemical, and geophysical data on the post-Acadian North Pole Pluton and its associated veins containing uranium and other metallic minerals have been used to establish criteria for identifying other favourable plutons.

Use of these criteria on granites of the anticlinorium has allowed identification of the Sn-, Mo-, W-bearing Burnthill, Trout Brook, Dungarvon, and Rocky Brook plutons as being most favourable for the occurrence of vein-type uranium deposits. A final report will be published in the near future by the Geological Survey of Canada.

At Heath Steele Mines, a three-year project jointly funded by the Federal and Provincial governments was completed under the direction of Drs. P.F. Williams and A.L. McAllister. The objective of this study was to provide a general assessment of the geological structures, define the distribution of stratigraphic layers, and ultimately, to use these data to locate additional ore reserves. Research on the structure and stratigraphy is being continued by Mr. Chris Moreton as the subject matter of his PhD program. Mr. G.A. Allcott is completing his MSc program on the application of geophysics to stratigraphic mapping.

A study on gold in the Brunswick No. 12 mine by S. LeBlanc,

working under Dr. Don Bachinski, was completed during the year. Gold-rich electrum occurs locked in pyrite-pyrrhotite veins in the footwall. The electrum is of such minute size that it would not be liberated by the current grind at Brunswick. In contrast, silver-rich electrum associated with cherty pyrite iron formation in the hanging wall is recoverable. Previously reported occurrences of electrum have been shown to be native bismuth.

Gold in quartz-albite veins in and on the flank of anticlinal fold hinges in a carbonate (siderite) facies iron formation (Lac Rougement, New Quebec) were studied by Andrew MacNabb working under Dr. Bachinski. Native gold occurs in pyrite. Alteration associated with the veins consists of ankeritization and tourmalinization.

An evaluation of the cost effectiveness of using the long-hole drilling mining method at the Lake George antimony mine was made by David Good under the supervision of Dr. Don Bachinski. Costs are concluded to be no different than those of the currently employed room-and-pillow approach. However, the life of the mine could be significantly extended by a change to the long-hole drilling method.

Dr. Bachinski's on-going studies on porphyry coppers continue.

Dr. Williams and a graduate student, Mr. W. Roberts, are finalizing their study of the structure of the potash in the Dennison Mine at Sussex as an aid to mine safety and improved economic assessment of its potash potential.

Dr. J.P.A. Noble with graduate student, Mr. Ali Chowdhury, is continuing projects on the diagenesis and fluid history of the Albert Formation in the Moncton basin. Several publications relevant to future oil and gas exploration in New Brunswick are in preparation and follow-up studies are in the planning stage.

Palaeontology

Dr. A. Logan is continuing actuopalaeontological studies of modern hard substrate communities in the Bay of Fundy with a view to ascertaining their value for palaeoecological reconstruction in the Mesozoic. Following completion of his project on competitive interactions of hermatypic corals in Bermuda Dr. Logan has commenced a new NSERC supported study on growth rates of two species of hermatypic corals from Bermuda and Barbados. The purpose of this study is to determine the effects of depth and latitude on the growth rates of these corals as an aid in palaeoecological and palaeoclimatic determinations.

Dr. Noble and his co-workers, Dr. G. Young and Dr. D.J. Lee, who graduated with a PhD in August of this year continue their studies on Palaeozoic fossil assemblages with emphasis on Silurian corals and stromatoporoids and the relation of the New Brunswick and Gaspe faunas to those of other circum-Atlantic areas. This study not only contributes to a better understanding of coral and stromatoporoid taxonomy, paleoecology and evolution, it also provides a means to a more accurate biostratigraphy and aids in the reconstruction of plate movements.

Dr. R.K. Pickerill is continuing work on the structure, composition, ecology and evolution of Silurian brachiopod-dominated communities of Arisaig (Nova Scotia). Additionally, he is making a study of the structure, composition and evolution of Ordovician marine benthic communities in Quebec with Dr. T.L. Harland and in Wales with Dr. P.J. Brenchley. He is also collaborating with Dr. M. Wade of the Queensland Museum, Australia, in a study of Cambrian jellyfish from the Saint John area. He continues his extensive trace fossil research in Spain, Portugal, Quebec, Newfoundland, New Brunswick, Alaska, Oregon, southern California and northern Greenland. Mr. D. Fillion, one of his PhD graduate students, is undertaking similar studies in Oregon and southern California.

Igneous Petrology

During 1988/89 the Igneous Petrology group included Dr. Todd Dunn, two graduate students (Mrs. Suporn Intasopa - MSc Candidate and Mr. Cuneyt Sen - MSc Candidate, and one undergraduate student (Mr. William Ratliffe - BSc (Hon.) May 1989). Group projects were quite varied and included field, analytical and experimental investigations of various aspects of Igneous Petrology and Geochemistry. The projects included:

Dr. Dunn was involved in a geochemical, experimental and isotopic study of the Lower Jurassic Minister Island dyke of the Passamaquoddy Bay area of SW New Brunswick (with Dr. Peter Stringer). This project was completed in ay 1989 and results were presented at the 1989 GAC/MAC annual meeting in Montreal. Drs. Dunn and Stringer are continuing their work on the dykes in SW New Brunswick.

Experimental determinations of the partitioning of the REE between clinopyroxene and basaltic melts at natural abundance levels (with Dr. S.R. Hart - Massachusetts Institute of Technology). In this collaboration Dr. Dunn is doing clinopyroxene crystallization experiments at high pressure using natural basaltic starting materials and Dr. Hart is analysing the crystal/melt pairs using the ion microprobe. The study is generating new REE partitioning data which will be directly applicable to modelling the petrogenesis of basaltic magmas.

Experimental determinations of the partitioning of Sr, Ba

and the REE between plagioclase and calc-alkaline melts at natural abundance levels. Plagioclase crystallization experiments have been done on a variety of natural calc-alkaline magmas from Mt. Adams (a Quaternary volcano in the Cascade Arc of western North America). The Sr and Ba partition coefficients are being determined by electron microprobe (using the Acton microprobe in the Igneous Petrology lab). The REE partition coefficients will be determined via ion microprobe with the MIT instrument.

Experimental determination of the diffusivity of ferrous and ferric iron in peraluminous sodium aluminosilicate melt (with Mr. William Ratliffe). This project involved the experimental determination of ferrous iron diffusivities at pressures from 0.1 MPa to 2.0 GPa. The project was completed in May 1989 and the results were presented as an invited paper at the Spring American Geophysical Union Meeting in Baltimore, USA. The 0.1 MPa part of the study was Mr. Ratliffe's BSc thesis project.

Mrs. Intasopa is continuing her geochemical and isotopic studies of the Permo-Triassic volcanic belt of Central Thailand.

Mr. Sen joined the group in May 1989 and is working on the empirical determination of the partitioning of a wide range of trace elements between calc-alkaline melts and a variety of minerals (e.g., ol, opx, cpx, and plag). The samples for Mr. Sen's study come from Mt. Adams in the Cascade arc. The data will be used to constrain the petrogenesis of the Mt. Adams magmas and will also be compared with experimental partitioning data determined by Dr. Dunn (see above).

In addition to the projects described above, Dr. Dunn has spent considerable time improving the experimental and analytical facilities available in the UNB Geology Department. The automation of the Acton microprobe has now been completed and the trace element procedures have been established for the XRF lab. Dr. Dunn is now building a Piston-Cylinder high-pressure high-temperature apparatus to generate pressures to 2.5 GPa and temperatures to 2000/C (completion expected in late 1989). With the completion of the Piston-Cylinder, the experimental facilities at UNB will be second only to those at the University of Alberta.

Metamorphic Petrology

Dr. J.G. Spray is continuing his investigations of metamorphism and melting in fault and shear zones. This is being carried out at both the field and experimental levels. Field work has centred on studies of thrust-related metamorphism beneath tectonically transported fragments of oceanic lithosphere (Spray 1988b) and studies of the fault systems in New Brunswick. In addition, the igneous and metamorphic genesis of the Fournier basic complex of northern

New Brunswick has been researched as part of Ms. P. Flagler's MSc thesis (completed June 1989). Experimental work has focused on the application of friction welding apparatus to the study of frictional heat phenomena in rock. The equipment enables fault movement to be simulated in terms of velocity, load (stress) and duration. Different fault rocks can be produced by this process (e.g., gouge at low power and melt at high power). The experimental technique has considerable potential for providing insight into fault dynamics and the generation of earthquakes (Spray 1988a). It is planned that these studies will also lead to a greater understanding of fluid movements and consequent mineralization processes occurring in fault zones. Ms. Lori Kennedy is continuing her MSc project on the high-temperature alteration of rock by drag cutters as part of the rock friction program. This work is also related to various rock excavation studies (Spray 1989).

Mineralogy/Crystallography

Dr. L.T. Trembath has been studying crystallization of feldspar in synthetic and natural systems in order to develop a better understanding of the crystallization and emplacement of granitoids. Due to ill health, Dr. Trembath's courses are being taught this year by Dr. A. Abdel-Rahman until May, 1990.

Regional Mapping Projects

Several members of the Department continue to be active in regional studies, Dr. Pickerill, in collaboration with Dr. K.L. Currie of the Geological Survey of Canada, and Dr. D. Nance of the University of Ohio, is involved in regional mapping in the Saint John area (New Brunswick). Professor I.M. Patel is working on the Precambrian-Cambrian boundary in New Brunswick. Dr. Noble is continuing his regional stratigraphic studies of the Silurian-Devonian of northern New Brunswick, while the Acadian cleavage in mainly Siluro-Devonian rocks in south-western New Brunswick and adjacent Maine and the structure of the Upper Devonian Perry Formation are being investigated by Dr. Stringer. The structure and extent of the Ministers Island dyke in southwestern New Brunswick and eastern Maine, and the mainland and offshore structure of the Lepreau Formation in southern New Brunswick, are being investigated by Drs. Stringer and Burke.

Dr. H.W. van de Poll continues his interest in applying specialized mapping techniques in his study of the Permo-Carboniferous of New Brunswick and Prince Edward Island emphasizing the lithostratigraphy, sedimentology, and physical diagenesis of these strata for an overall analysis of the palaeogeographic paleoclimatic and structural evolution of the Maritimes Basin during Pennsylvanian time.

Postgraduate students working under Dr. Williams' direction continue mapping in the Dunnage Zone around eastern Notre Dame

Bay (Newfoundland), in the Meguma Terrane and in the vicinity of Thompson Mine, Manitoba.

Pat Flagler has completed mapping components of the Elmtree (Fournier) Complex as part of her MSc thesis and is currently completing a remote sensing report of the Fournier area for DNRE.

Sedimentology

Dr. Noble is continuing his long-range sedimentological studies emphasizing the diagenesis and burial histories of the Silurian-Devonian basins in northern New Brunswick and Gaspe. In particular comparisons of diagenesis in the basins and adjacent shelf borders, is shedding light on the structural and burial histories of these marginal zones. A similar, but much better exposed (and much better known stratigraphically) foreland basin in the Alps, is now being studied for the information it provides on the less well known Appalachian basins.

Dr. Pickerill, in addition to contributing sedimentological work to a regional study of the Saint John Group, is also continuing his extensive studies of Middle Ordovician sedimentation of the Trenton Group carbonates of Quebec. Two of his graduate students are involved in sedimentological studies in the Carboniferous of Cape Breton and Lower Devonian of central New Brunswick.

In addition to developing specialized sedimentological mapping techniques for regional Basin analysis, Dr. van de Poll and Professor I.M. Patel are continuing their studies on physical diagenesis. These studies concentrate on post depositional processes related to compaction of the sediments. Their findings suggest that many sedimentary features, including grain-matrix and clastic ratios and certain types of sedimentary structures may not entirely be the result of primary processes, but can also be attributed to secondary processes of sediment remobilization during compaction. This work is on-going in conjunction with Carboniferous Basin analysis and has potential applications in facies analysis, palaeoseismic interpretations, syndepositional tectonics and petroleum reservoir studies.

Structural Geology

Dr. J.C. White is examining microstructural and micro-chemical characteristics of deformed rocks and other comparable materials, with emphasis on the application of electron microscopy. Mechanical twinning in triclinic K-feldspar has been recognized for the first time, in this case associated with a metasomatic precious-metal deposit. The microstructures have placed distinct constraints on the timing of metasomatism and the observed deformation. Examination of deep shear zones

has led to preliminary formulation of a limiting parameter for preservation of microstructures during rapid, thrust-related exhumation. Installation of the new analytical SEM and EDS system for the TEM will allow interfaces in fine-grained material (i.e., Bathurst camp type) to be quantitatively studied. Characterization of shock deformed minerals at Manicouagan, Quebec has indicated two types of 'glass' as well as previously unrecognized myrmekite-like feldspar intergrowths indicating post-shock alteration.

Dr. Williams and students are working on major faults in Atlantic Canada including the Dover Fault, Newfoundland with Mr. A. Caron, faults in southern New Brunswick with former student Mr. A. Leger, the Chanceport-Lukes Arm Fault system in Newfoundland with Mr. B. LaFrance, and the Indian Islands Faults, Newfoundland with Dr. J. Urai. The objective of these studies is to synthesize the Appalachian ductile and brittle faulting history as a basis of understanding amongst other things its influence on Carboniferous sedimentation and emplacement of quartz and calcite veins, many of which are related to the faults.

Research by Post-doctoral Fellow, Dr. Laurel Goodwin, conducted under the auspices of Paul Williams, is focused on an analysis of the structural evolution of tectonic boundaries in the Newfoundland Appalachians, with particular emphasis on the Baie Verte and Grubline areas. Funding is provided through Lithoprobe. The main goal of the project is to provide geologic constraints on interpretations of seismic data obtained from the Lithoprobe East Transect. Additional objectives include a study of the structural behavior of terrane boundaries over time and an investigation of inhomogeneous deformation of anisotropic materials.

Dr. Williams is also continuing his research with Dr. D. Keppie and Mr. S.J. Hwang on the structural implications of shear zones in the Shelburne, Nova Scotia area. Another PhD graduate student, Shoufa Lin, has commenced a structural project in the Cape Breton Highlands. In addition, Dr. Williams completed an MDA project to investigate with Dr. C. Hy the geological history of gold-bearing veins in Nova Scotia, and is involved in a project at the Thompson Nickel Mine, Manitoba with Dr. C. van Staal and Mr. W. Bleeker.

Dr. Williams is involved in three joint projects with the Geological Survey of Canada. Two graduate students (MSc) Christopher Beaumont-Smith and Robin Wyllie are conducting structural mapping work around the Back River Complex and the Archaean rocks of the Bathurst Inlet area (NWT) respectively. GSC supervisors are Maurice Lambert and Jack Henderson, while Robin Wyllie's project also receives industrial funding. Two post-doctoral research fellows, Adrian Park and Steven Ralser, are remapping the Tavani area (Keewatin, NWT) with Subhas Tella (GSC) on an MDA-funded project now in its second year. This

project emphasizes stratigraphy, structure, geochemistry and geochronology with relevance to the economic potential of an Archaean greenstone belt.

Dr. Williams is also conducting computer simulation experiments on the development of folds during shear straining.

Neotectonics

Drs. Burke and Stringer are continuing an investigation of potentially neotectonic features in southwestern New Brunswick under a research agreement with EMR. A map of faults on Deer and Campobello islands at a scale of 1:50 000 was compiled by Dr. Stringer from published maps and reports and unpublished fieldwork and is being used as the basis for the investigation of NW-trending faults and their relationship to earthquakes in the region.

Drs. Broster and Burke completed a joint project in Saint John on the neotectonic implications of displaced striae in bedrock. The results are to be submitted for publication this fall.

Deformation Studies

The Centre for Deformation Studies in the Earth Sciences has now been formally established at the Department of Geology. The Centre comprises members of faculty who have a common interest in the deformation of the earth, its constituent materials and attendant processes. Present members include Drs. Broster, Burke, Spray, Stringer, van de Poll, White, and Williams. The membership represents a wide variety of research interests including glaciogenic and soft-sediment deformation, earthquake seismology, neotectonics, fault rock generation, experimental and computer simulations, shear zone rheology, microstructural analysis and regional mapping. The formation of the centre underlies a commitment to enhance the existing research programs of participants and encourage the development of new fundamental and applied research in deformation studies at the individual and group levels.

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# PART IV

## RESEARCH AND PRODUCTIVITY COUNCIL

# MINERAL- AND ENERGY-RELATED ACTIVITIES AT THE NEW BRUNSWICK RESEARCH AND PRODUCTIVITY COUNCIL

Compiled by John A.R. Stirling

## INTRODUCTION

The Research and Productivity Council (RPC) is a contract research organization serving industry in New Brunswick, Canada, and abroad. Activities are directed at geological research and exploration, productivity enhancement, process optimization, product innovation, quality control, technology transfer, environmental protection, worker safety, and other tasks for the benefit of industry in manufacturing, natural resource development, and energy matters.

RPC's services to the mineral industry encompass the disciplines of petrology, mineralogy, lithogeochemistry, mineral analysis, mineral processing, hydrometallurgy, pyrometallurgy, analytical chemistry, fuel technology and materials science. Petrologists, mineralogists, mineral processing engineers, metallurgists, chemical engineers, chemists, NDE experts, and physicists offer a wide range of expertise in all of the above-mentioned disciplines.

## METALLURGY, WELDING, AND NON-DESTRUCTIVE TESTING SERVICES

The Engineering Materials Department has been active in providing a consultancy service and field inspections for various coal, potash and other mines in New Brunswick. Metallurgical investigations of failures in a wire rope, a ladle, rock bolts, a pinion, bearings and a shaft have been carried out this year. Preventive maintenance inspections were performed on a wide range of equipment such as draglines, heat exchangers, water lines, boiler tubes, winding gear, axles, etc.

## ELECTRONICS

The Electronics Department is developing a data acquisition and control system to improve operating efficiency of a dragline for NB Coal Ltd. This project, which is jointly funded by NB Coal and CANMET/EMR (through the committee on Atlantic Coal), will ultimately include expert system aspects to advise operators on dragline performance. The 3-year project includes a strain monitoring/alarm system (completed), a lubrication control system, a performance monitoring system, and an advisory system for operators.

The Electronics Department has also completed a state-of-the-art study of electro-osmosis for the Canadian Electrical Association. This technology is now being applied by the Minerals and Fuels Technology Department at RPC to do a study of coal dewatering.

**MINERALOGY**

The mineralogy group has carried out studies for most of the mines in the Province, Department of Natural Resources and Energy, University of New Brunswick, and exploration companies. The major studies were the mineralogical evaluation of part of the circuit at Brunswick Mining and Smelting, and the study of alkali-aggregate reactivity and mineralogy and geochemistry of the PCA and Denison Potacan potash deposits both of which are MDA projects sponsored by CANMET.

Investigation of alkali reactivity of the New Brunswick concrete aggregates, initiated three years ago, has been continued. Analytical techniques for identification and compositional characterization of reaction products in hardened concretes have been developed. The techniques employ a Scanning Electron Microscope, Electron Microprobe and an Optical Microscope. Two types of products have been distinguished, namely primary silica gels with the K:Ca ratio >1.0 and secondary gels with the K:Ca ratio <1.0. Aggregate particles containing primary gels are positively identified as reactive. Further work on petrographic and chemical characterization of reactive rock types, which appear to be certain argillites and greywacks, is planned. This work will eventually be published in a CANMET report.

A detailed mineralogical examination of the Brunswick Mining and Smelting concentrator has been completed (Coleman et al. 1989). Samples from various process streams were analysed using automated image analysis techniques. The data have been adjusted using a computerized material balance procedure (CANMET's MATBAL5). Careful examination of the results has delineated areas for further study to assess the possibilities for improved productivity.

The study of mineralogy and geochemistry of the PCA and Denison Potacan potash deposits has been completed and a confidential report has been sent to CANMET. Although most of the results are still confidential the preliminary results of the Br geochemistry (Stirling et al. 1988) and the image analysis techniques have been published (Stirling 1989). The remaining data will probably become public information in the near future.

**PROCESSING**

Several hydrometallurgical projects have been completed or are ongoing. A pretreatment process for refractory gold ores was investigated using the chlorine as an oxidizing reagent. This pretreatment process allows the refractory gold locked in to be amenable to conventional cyanidation. In one example, gold extraction by cyanidation was increased from 48% to 98% with the pretreatment. An investigation was carried out to develop a recovery process for nickel, copper, and cobalt from

a solution produced by heap leaching of St. Stephen nickel deposits. A simple sulphidation recovered most of these elements, producing a mixed sulphide concentrate saleable to existing smelters. A project funded jointly by CANMET and Canadian zinc producers to further study the development of an electrochemical method for the prevention of iron compound scaling has been started.

Two MDA projects have commenced. One is to investigate methods to recover gold from heap leach solutions, specifically solutions obtained from leaching gold-bearing ore from the Cape Spencer area of New Brunswick. The project will evaluate various gold recovery processes as well as providing preliminary design data for a heap-leach operation.

The second project is an investigation of the use of flotation columns for the recovery of potash. A laboratory flotation column supplied by DNRE is being tested with various KCl containing streams and the results are being compared with conventional flotation.

Successful preliminary flotation projects have been undertaken with ores from East West Caribou Mining's sulphide deposit and Stratabound Mineral's Captain North Extension orebody. Other projects include recovering gold and base metals from an old tailings deposit; dewatering of fine clean coal; and comminution tests using roll crusher to determine whether a coarser grind could be achieved without loss of liberation.

Environment and process engineering assistance on behalf of Maritime Battery Ltd. has lead to the construction of a five (5) tonne-per-hour battery breaking plant. The plant will crush whole scrap acid lead batteries and separate them into component parts for resale of the lead fractions to the smelter in Belledune. A preliminary technical feasibility study investigated another recycling industry for the recovery of Platinum Group Metals from scrap automobile catalytic converters.

A two-stage reduction/oxidation fluidized bed roasting facility was constructed and commissioned in the pilot plant. The facility is designed to treat refractory arsenical gold concentrates.

High-temperature filtration technology was developed and utilized for the treatment of baghouse dusts to separate volatile and non-volatile components. The high efficiencies of the high temperature filtration utilizing either sintered metal or woven ceramic results in high-grade condensate and a recoverable precious- or base-metal, non-volatile calcine.

**FUEL TECHNOLOGY**

The Province is continuing to encourage development of its oil-shale resources. Testing of oil recovery from shales by RPC has indicated the conditions necessary to maximize oil yield.

Other work on oil shale has involved its use as a fuel. Test results on controlling sulphur emission by the combined combustion of the shale with Minto coal have been useful to the New Brunswick Electric Power Commission in the operation of the 22 MW demonstration facility for circulating fluidized bed combustion at Chatham.

**ANALYTICAL AND PROCESS CHEMISTRY**

The analytical services group carries out a wide range of support activities for the NB Mining Sector. In the past year, the group has carried out a number of mineral-related projects such as:

1. The development of methodology and laboratory set-up for a new mining operation,
2. The analysis of a large number of coal, oil-shale, and fuel samples,
3. Determination of the alkaline reactivity of aggregates,
4. Chemical and biological studies of the acid-generating potential of waste rock,
5. Accredited analysis of fertilizer samples, and
6. Assays on mining and metallurgical samples inclusive of environmental waste waters, etc.

The Occupational, Health and Safety Group has also assisted the Mining Sector in areas such as air-quality monitoring and analysis, asbestos surveys, and hazardous materials surveys.

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